

Science Focus

“So long, and thanks for all the fish”

What could
ALIEN LIFE LOOK LIKE?

New test finds
CONSCIOUS COMA PATIENTS

MASS EXTINCTION...



CAN WE STOP IT?

(AND WHAT CAN WE LEARN FROM THE DINOSAURS' DEMISE?)

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Getting to know a
visitor from another
solar system

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How police
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Burning forests
in the name
of science

Diet

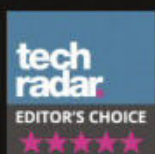
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could be good
for your brain

Climate Change

Can planting
trees get us to
carbon neutral?

SENSATIONAL SIX

ALL-ROUND CREATIVE GENIUS



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How can meat-flavoured crisps be vegetarian? → p86



FROM THE EDITOR



In the 3.5 billion years that life has existed on this planet, it's nearly been wiped out five times. On each occasion, the complex web that supports life on Earth has been stretched to breaking point, killing more than 75 per cent of the species present. Now it looks like it's happening again.

In the last few years, a number of reports have sounded the alarm for another extinction event. They point to the global weirding of our climate and an extinction rate that's 1,000 times faster than we would expect naturally. It's grim reading.

But there is one difference this time. Us. We have the means to make a difference, not just to save our own skins, but the other species around us. The tricky part is knowing which part of the web needs our help. Fortunately, there is one place we can look for clues: the past.

The complex sequence of events that leads to each of the last five extinctions can tell us what happens when the planet's ecosystems begin to collapse. If we can fully understand the fate of dinosaurs, we might be able to understand and even change our own destiny. Turn to p48 to find out what we're digging up.

Daniel Bennett

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...



Television

The affable Jim Al Khalili makes a long overdue return to BBC Four this month for his new six-part series *Revolutions*, which looks at the inventions that shaped our world. bit.ly/bbc_revolutions

iPlayer

The *Horizon* team goes behind the scenes at the NHS as they build a proton beam therapy clinic – one of the most technologically advanced cancer treatments in the world. bit.ly/horizon_cancer_cure

Radio

What makes someone good at predicting the future? In a world of uncertainty, the *CrowdScience* team discovers the world of super forecasters. bit.ly/crowd_forecast

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SALEYHA AHSAN

On 9 August almost four million Muslims are set to journey to Mecca for the Hajj – the annual Islamic pilgrimage. *Trust Me, I'm A Doctor* presenter and Hajj veteran Saleyha gives us the lowdown on getting there safely. → p24



BEN HOARE

Liberace has nothing on nature's most flamboyant animals. *BBC Wildlife Magazine*'s Ben unravels the science of showing off. → p40



HAYLEY BENNETT

This summer, researchers in Utah deliberately set fire to an area of woodland in an attempt to discover how wildfires spread. Science writer and editor Hayley tells us what they found. → p64



MİĆO TATALOVIĆ

With the discovery of Earth-like planets and missions gearing up to spot life on other planets, Mićo asks some of the world's leading biologists what we might expect to find out there. → p70

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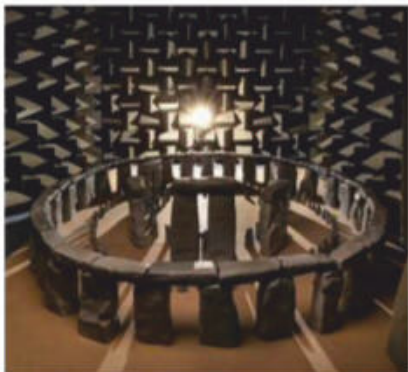
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“We have demonstrated that we can tie these electrodes around small nerve bundles”

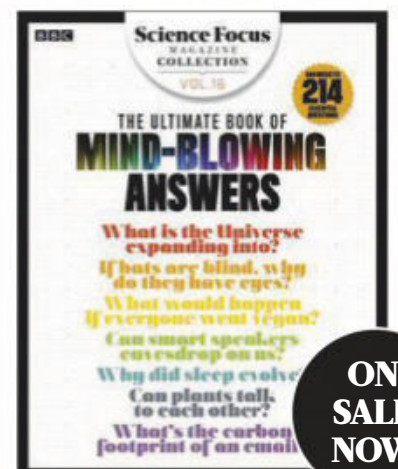
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EYE OPENER

Virtually there

DÜSSELDORF, GERMANY

Here, the audience at Roncalli Circus Theatre experiences the first holographic circus animals. Roncalli's founder and director Bernhard Paul, and chief digital officer Markus Strobl, led a team of 15 people to create life-sized elephants, stampeding horses, and a huge, swimming goldfish.

Bernhard wanted to include the technology in the circus after he watched a hologram of the late singer Prince during Justin Timberlake's 2018 Superbowl performance.

"I was so impressed by the holographic technique," says Paul. "As a circus, the audience is our boss, and when you feel the audience does not approve of something then you have to change it."

The 360° holograms are made by projecting 11 different laser beams onto a nylon-based screen that is set up around the ring. The projectors are connected via a cloud computer that uses as many as 3,000 processors to generate the visuals.

CIRCUS RONCALLI

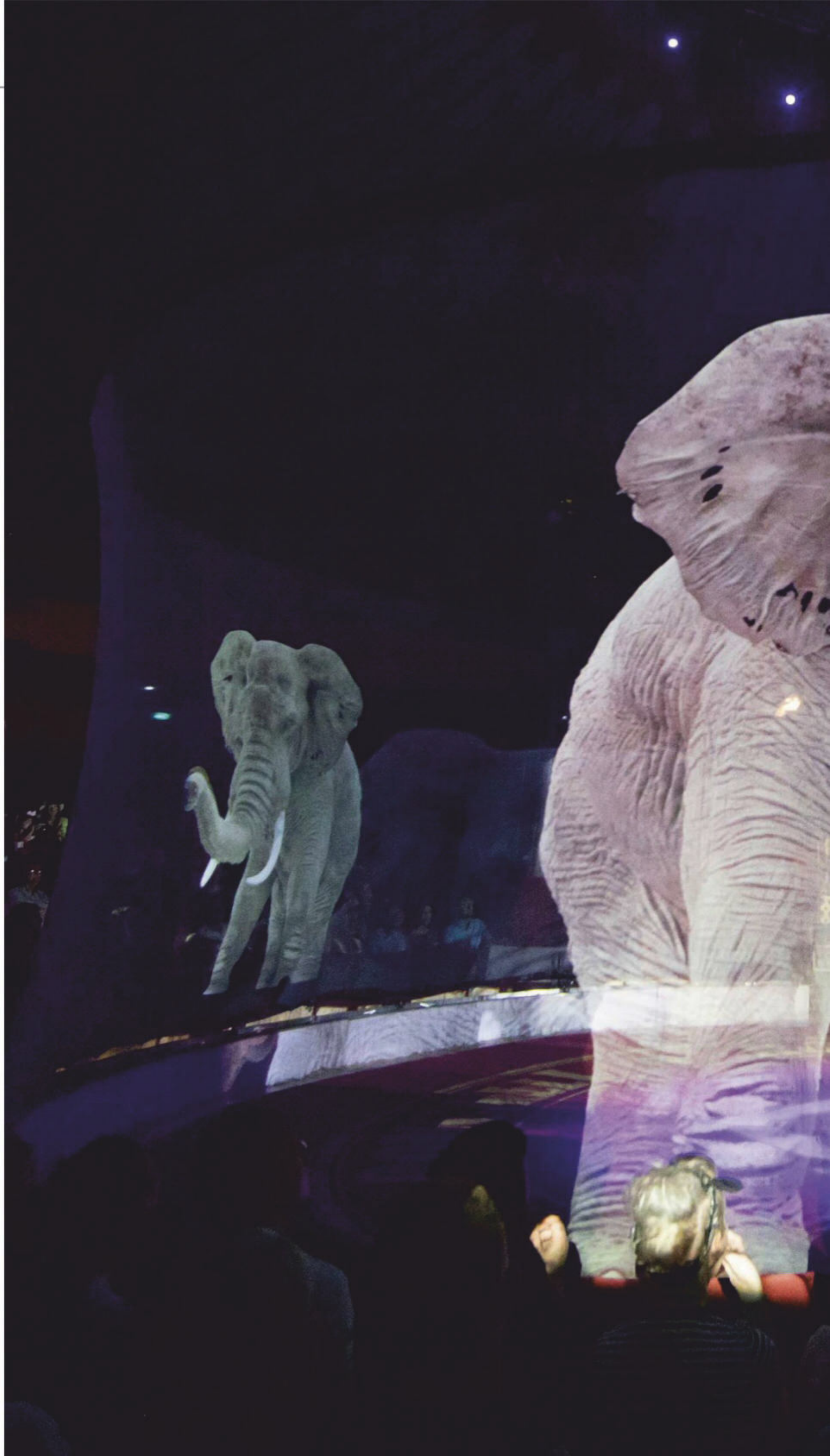
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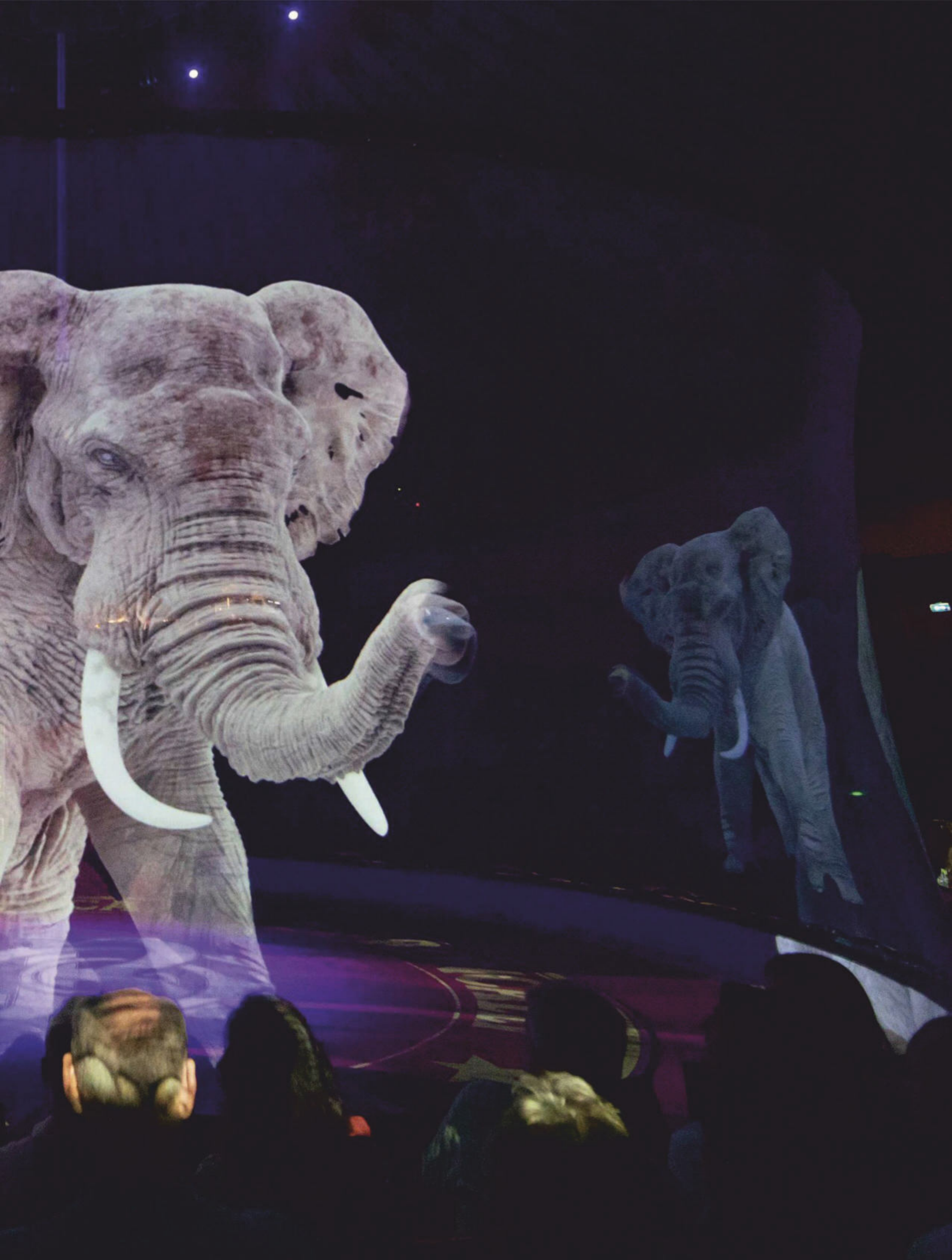


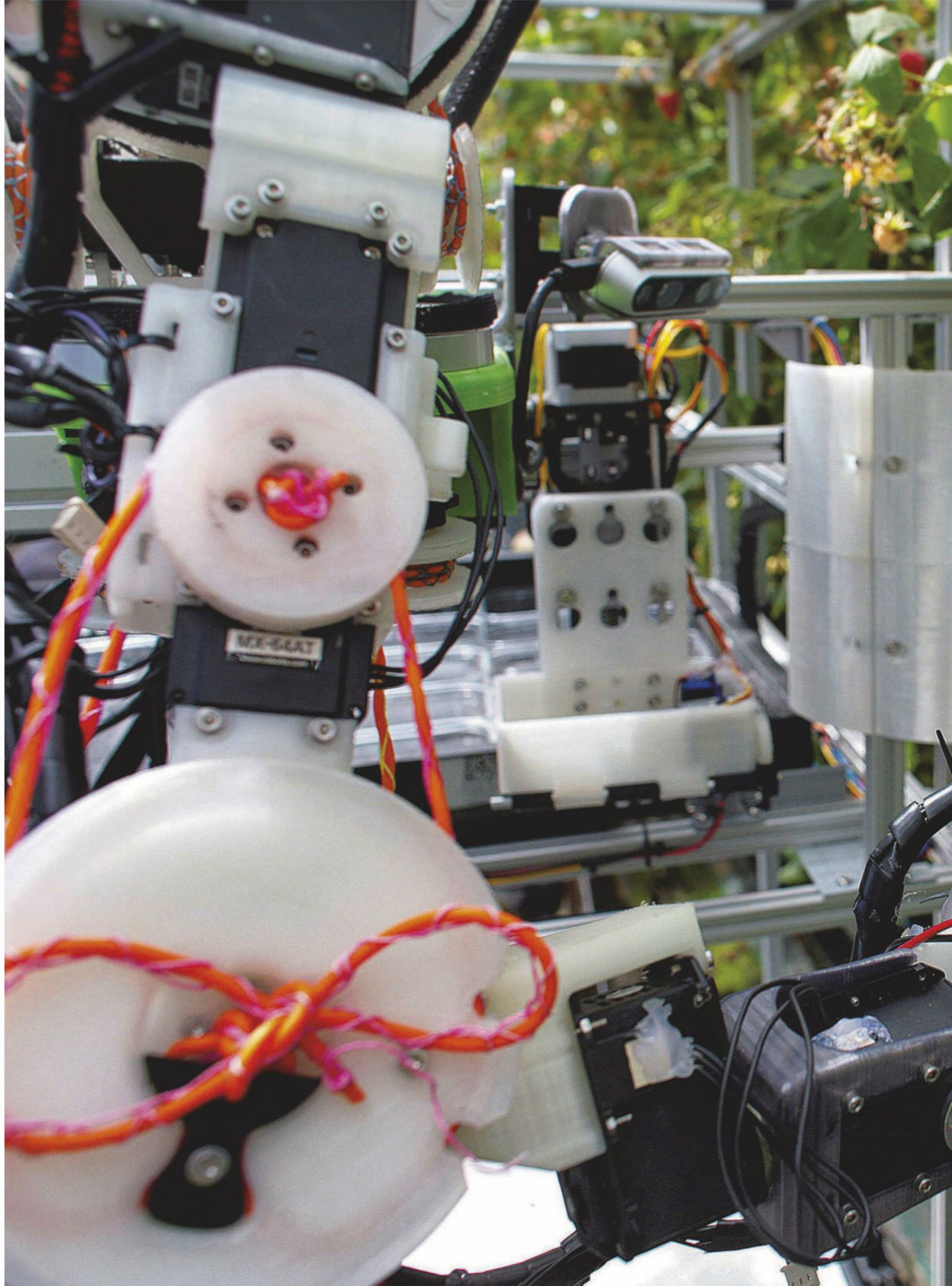
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EYE OPENER

Berry smart

CHICHESTER, UK

The world's first raspberry-picking robot earns its keep at a West Sussex farm. The autonomous machine is a variable-stiffness robot arm that's able to replicate the movements of a human arm. The tech was developed by Fieldwork Robotics, a team from the University of Plymouth headed by Dr Martin Stoelen.

"Currently, manual harvesting represents a large portion of producers' total costs," says Stoelen. While human workers can pick around 15,000 raspberries in one eight-hour shift, Fieldwork's robot can collect more than 25,000 in a day. Stoelen is certain that there will always be jobs for people associated with agriculture. "But it might be that in a decade's time, instead of spending hours in the cab of a tractor, your role is managing robots such as those we are developing."

EYEVINE

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CONVERSATION

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LETTER OF THE MONTH

Old wives' tales

You managed effectively to dismiss the old wives' tale about cows lying down before rain (July, p82) but when I turned the page, I found you are perpetuating another old wives' tale: that earwigs have ear-shaped wings. An old wife would never have seen an earwig's wings, as common earwigs never, if ever, fly. To see the wing, you must dissect the insect. Earwigs do get into ears – as someone who has experienced an insect-infested ear, I feel I can talk with some authority on the subject! I suggest that the 'wig' part of the word was not derived from 'wing' but is the colloquial verb 'to wig'.

Kim Taylor, Guildford, via email

The word 'earwig' comes from the Old English *ēare wicga*, which means 'ear beetle'. There is no doubt that they do occasionally find their way into human ears, but it's a rare

enough event to make me question this literal interpretation of the name, and I thought it was interesting to raise the alternative explanation based on their wing shape. This idea has been put forward by some entomologists (none of who are old wives, as far as I am aware). The verb 'to wig', meaning 'to scold', only dates from 1829, according to Merriam Webster, and the slang sense meaning 'to freak out' is even newer, so neither of them seem likely to have influenced the name of the insect.

Luis Villazon, Q&A expert



WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **50th Anniversary Moon Map** by the UK's official cartographers, **Ordnance Survey**. Printed on real canvas and presented in an oak frame, the map depicts a 1,000 x 1,350km area of the lunar surface with the Apollo 11 landing site at its centre, and was created using data from NASA's Lunar Orbiter

Laser Altimeter and Kaguya Terrain Camera. **ordnance-survey.co.uk**



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Chick lives matter

With regard to the article 'An eggcellent breakfast' (July, p63), whether eggs are healthy or not for humans, they are certainly very unhealthy for the hens that lay them and, more immediately, the unwanted male chicks which are macerated soon after birth.

Alan Watson, via Twitter

There is certainly an ethical case to be made for not eating eggs, or indeed exploiting animals in any way. But unless you are prepared to become a vegan, then I think eating free range eggs is acceptable.

Michael Mosley, BBC Science Focus columnist

Bran for breakfast

I much appreciated Michael Mosley's myth-busting article on how the cholesterol you eat has almost no effect on your blood cholesterol levels (July, p63). The media and the medical profession have given inconsistent messages about foods over the years (don't start me on butter vs margarine!) so it was good to have some clarity and the article provided a reality check in that most cholesterol is actually produced in the liver.

But there are foods that WILL affect your blood cholesterol levels – and lower it. Research has shown that there are a number of foods that help reduce cholesterol levels, two notably being porridge and oat bran. My personal experience is that after



Eggs: a healthy breakfast for people, less so for chickens

having a daily serving of oat bran – in combination with plant sterols and a little light exercise – my cholesterol fell from over 8 to 6 in just three months, leading to my GP asking me, "How have you done this?" as apparently it's unusual without statins.

Bonus that now Michael says we can eat eggs again!

Markos Tiris, via email

Conscious Universe?

Regarding the depressing interview with Prof Nicholas



“I’M WILLING TO BET YOU THAT IN THE NEXT 20 YEARS WE’LL FIND SOME LIFE. IT WILL PROBABLY BE MICROBIAL LIFE SQUIRTING OUT OF ENCELADUS, OR MAYBE EUROPA”

SETH SHOSTAK, SETI INSTITUTE, p74

Money (Summer, p90) about his insightful book on our flawed species, *The Selfish Ape*, I think he misses one profound point. That is, unless there are intelligent extraterrestrials out there, we are unique. Through us, matter and energy has become conscious and can think about itself. Indeed, through us, the Universe has become conscious.

Now, the paradox is that humans with a cosmic perspective and thoughtful outlook are in a tiny minority and the rest of humanity is a destructive selfish horde, as Money describes.

Ronald Barnes, via email

Humans aren’t the only ones who can think about themselves. Scientists can test whether an animal has self-awareness with the mirror test: put a mark somewhere visible on the animal’s body and then show them their reflection. If the animal tries to remove the mark, then they must recognise themselves in the mirror.

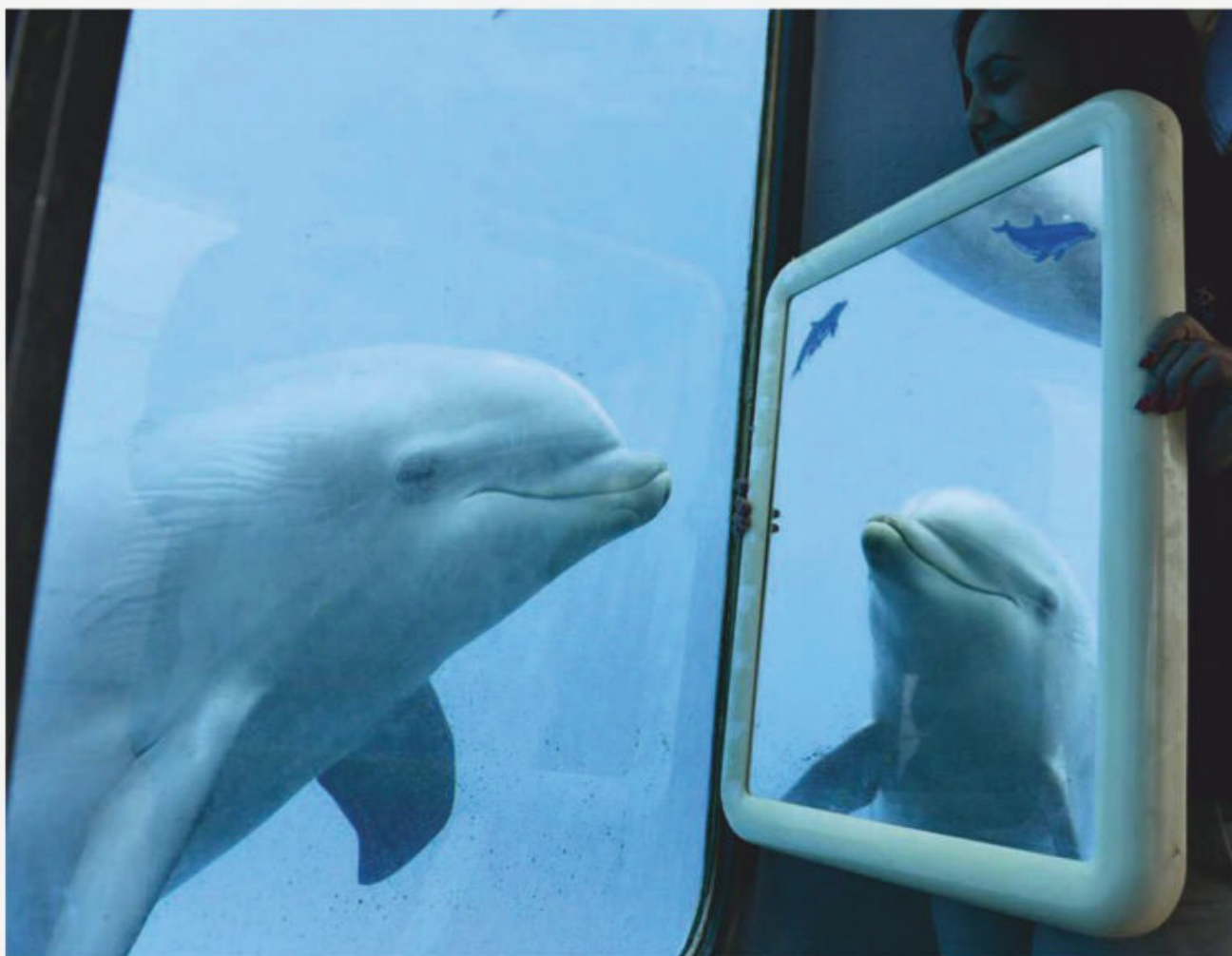
Chimps, elephants, dolphins and magpies have all passed this test (though most dogs fail).

Sara Rigby, online assistant

Oops...

In the June issue (p90) we referred to Dr Monty Lyman as a dermatologist. He is, in fact, a junior doctor.

“MATTER AND ENERGY HAS BECOME CONSCIOUS AND CAN THINK ABOUT ITSELF. THROUGH US, THE UNIVERSE HAS BECOME CONSCIOUS”



Dolphins, magpies, elephants and chimps all pass the mirror test, displaying some degree of self-awareness

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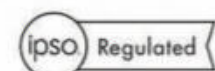
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SOUND OF STONES

Did Stonehenge have acoustic properties? **p29**

ORANGS RECOVER

Conservation of orangutans sees success in Borneo **p17**

TUNE IN

Our brains are programmed to hear music **p18**

SEALS' GOT TALENT

Three grey seals perform *Twinkle, Twinkle* **p19**

DISCOVERIES

Brain scans discover consciousness in coma patients

The finding could help predict the chances of recovery in brain-injured patients

Some patients that become unresponsive following a significant brain injury retain a degree of 'hidden consciousness' and are more likely to make a recovery, neurologists at Columbia University have found.

The team used specially designed computer software to analyse standard electroencephalography (EEG) data collected from 104 unresponsive patients to search for specific patterns of brain activity after asking them multiple times to open and close their hands. The idea being that even though they are unable to respond to verbal commands by speaking or moving, the patients are still in some way conscious and can understand the commands.

They found that nearly one in seven brain-injured patients in intensive care units (ICU) shows evidence of hidden consciousness just days after injury. ●



Earth overshoot day When did different regions hit it? **p20** **Neuralink** Elon Musk's latest enterprise **p22**
Plant trees for the planet Can we stop climate change by planting billions of trees? **p26**

News in brief

DITCHING MEAT COULD HELP FIGHT DIABETES

A plant-based diet reduces the risk of type 2 diabetes, according to a new Harvard study.

Eating a healthy mix of fruit and veg, as well as nuts, legumes and grains, while avoiding meat, reduces the chance of developing the disease by 23 per cent. People who also avoid potatoes, white flour and

sugar reduce their risk even more. The researchers believe this could be because plant foods lower blood pressure and improve the body's sensitivity to insulin, the hormone that controls the body's blood sugar levels. These foods also reduce weight gain, another risk factor for type 2 diabetes.



×

“Within four days of the injury, 15 per cent of the still-unresponsive patients had brain activity patterns”

● “This study shows that some patients who are unresponsive for days or longer may have cognitive processing capabilities sufficient to distinguish commands, and those patients have a higher chance of recovering,” said associate professor of neurology Dr Jan Claassen, who led the research. “One of the most challenging problems in the ICU involves predicting recovery, and not just survival, for patients who are unconscious after a brain injury. Since the first studies describing hidden consciousness, we’ve been looking for a practical way to do this in the early days after brain injury, when treatment decisions that affect outcomes are often made.”

Within four days of the injury, 15 per cent of the still-unresponsive patients had brain activity patterns on at least one EEG recording, suggesting hidden consciousness. Among these, 50 per cent improved and were able to follow verbal commands before being discharged from the hospital, versus just 26 per cent of those without such brain activity.

A year later, 44 per cent of patients that showed the hidden consciousness brain activity patterns were able to function independently for up to eight hours each day, compared with only 14 per cent of those without. However, approximately one-third of patients in each group – those with early EEG evidence of hidden consciousness and those without – passed away.

The decision to withdraw life-sustaining therapies from patients who appear to have little chance of recovery are frequently made within the first weeks following brain injury, the researchers say. This can lead

to difficult discussion between families and healthcare providers.

“Though our study was small, it suggests that EEG – a tool that’s readily available at the patient’s bedside in the ICU in almost any hospital across the globe – has the potential to completely change how we manage patients with acute brain injury,” said Claassen.

Bigger, more thorough, studies are now needed to investigate the technique further, the researchers say.



Brain scans have revealed that some coma patients still have cognitive processing abilities. This discovery could revolutionise how we treat and think about brain injury

For the latest science news, visit sciencefocus.com



EATING PEANUTS MAY PREVENT ALLERGIES

Infants who eat small amounts of peanuts are less likely to develop an allergy, a study found. The research involved 640 children, aged 4 to 10 months, who were at a higher risk of developing a peanut allergy, such as those with eczema or food allergies. Of those that avoided peanuts, 20 per cent developed an allergy after five

years, compared to only 3.2 per cent of those who ate peanut butter weekly. Researchers suggest that parents introduce a weekly dose of one teaspoon of peanut butter into their child's weaning diet. However, allergy testing in babies with severe eczema or other food allergies is recommended beforehand.

"You ain't got nothing on my moves, Craig Revel Horwood!"



ZOOLOGY

It takes cockatoo to tango

Scientists search for origins of dance

Birds just wanna have fun! Snowball the cockatoo, who first gained internet fame in 2007 dancing to the Backstreet Boys' *Everybody (Backstreet's Back)*, has been shaking a tail feather for science.

The researchers, from Tufts University and Harvard University in the US, were looking to understand why he can move to the beat when primates such as gorillas and chimpanzees, humans' closest relatives, can't.

Snowball displayed an impressive range of 14 different dance moves, plus two composite moves. While dancing to 80s classics *Another One Bites The Dust* and *Girls Just Wanna Have Fun*, the sulphur-crested cockatoo bounced, lifted his foot, posed with his crest raised, did some headbanging and even showed off a move the researchers call 'voguing'. "What's most interesting to us

is the sheer diversity of his movements to music," said Prof Aniruddh Patel, who took part in the research.

The team says that Snowball's ability to come up with new moves, as well as his ability to improvise a different dance each time he hears a song, shows flexibility and creativity. So why can humans and cockatoos boogie, while gorillas and chimps can't even tap their feet to the beat? It comes down to the fact that we share a number of features with the birds, such as the ability to learn and copy voices, imitate movement, and form long-term relationships, all of which add up to a fondness for moving to the music, the team say. For us, dancing is a social activity, and we're more likely to dance in a group than on our own. The researchers now want to find out if the same is true for Snowball.



SOCIAL MEDIA USERS

There are ongoing debates as to the pros and cons of social media sites, but researchers at Edge Hill University have found that WhatsApp has a positive impact on wellbeing. Connecting with friends and family through the app was shown to raise self-esteem and make users feel less lonely.

ECO-FRIENDLY MENSTRUATORS

A review of sanitary products suggests that menstrual cups – a reusable alternative to pads and tampons, which are largely made from plastic and produce greenhouse gases in production – are safe and just as unlikely to leak as their disposable counterparts.

Good month

Bad month

BITCOIN MINERS

The virtual currency relies on computer processing to record and maintain the Bitcoin network. But a team at the Technical University of Munich have found that the use of Bitcoin generates approximately 22 megatons of CO₂ emissions each year – similar to the carbon footprint of Las Vegas.

EXTERMINATORS

Dystopian writers have long predicted that cockroaches will rule post-apocalyptic Earth, but their invincibility may now be a thing of reality. German cockroaches were found to be resistant to almost every type of insecticide used to treat an infestation, say researchers at Purdue University, US.



AIR POLLUTION AGES THE LUNGS

Scientists have found further evidence that breathing in polluted air damages the lungs and reduces life expectancy. Analysis of more than 300,000 people in the UK found that those who were exposed to higher levels of air pollution had reduced lung function (as measured by spirometry tests which

involve exhaling in one forced breath). This reduction was equivalent to at least one year of ageing. The researchers, based in Canada, Switzerland and the UK, also found that those who were exposed to more pollutants had a higher risk of developing chronic obstructive pulmonary disease (COPD).



Trending

YOUR GUIDE TO WHO'S SAYING
WHAT ABOUT THE HOTTEST TOPICS
IN THE WORLD RIGHT NOW

#AlanTuring

The Enigma codebreaker and computing pioneer has been announced as the face of the new £50.

MIT CSAIL

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The binary on the ribbon that runs across England's new 50-pound note is 23 06 1912 in decimal – Alan Turing's birthday.

Stephen Fry

@stephenfry

Well that's just great news about Alan Turing – I have been pushing for this for years, though I thought it might have been rather good for him to share the £50 note with Ada Lovelace. Both pioneers of computing science, both underappreciated in their lifetimes.

**#Apollo50**

On 16 July 1969, NASA made history by launching humans to the Moon. The crew safely arrived on 20 July.

Buzz Aldrin

@TheRealBuzz

50 years ago today, Neil Armstrong, Mike Collins and I launched into space on a mission of enormous importance. God bless the 400,000 Americans who helped us get to the Moon and back. Together, we Americans can do anything! Never forget July 16, 1969! #Apollo50

Scott Kelly

@StationCDRKelly

50 yrs ago today, Armstrong, Collins and Aldrin began humanity's greatest journey. #Apollo11 not only set a trajectory to the Moon but also to our future. #Apollo50

Stemettes

@Stemettes

The #Apollo50 Moon landing anniversary is a reminder of the importance of #WomenInSTEM #hackthemoon #MoonLanding50

#BigButterflyCount

This month saw the launch of the Big Butterfly Count, a nationwide citizen science project aimed at assessing the environment's health.

Chris Packham

@ChrisGPackham

I have quite a few small whites and meadow browns in the garden and yesterday a single peacock. What does this mean? Not much in anecdotal isolation! Which is why @savebutterflies #bigbutterflycount is so important – turning our observations into science.

Matt Lucas

@RealMattLucas

Being in nature can have a powerful, grounding effect, with research indicating that it can help alleviate mental health problems like depression and anxiety. Sit back, relax and take part in @savebutterflies #BigButterflyCount



KEEP IN TOUCH



@SCIENCEFOCUS

**#RhinoRays**

Giant guitarfishes and wedge fishes, known collectively as rhino rays, are the world's most threatened marine fish, according to the IUCN Red List.

Meaghen McCord

@MeagAShark

#RhinoRays set to bypass #sawfishes as the most endangered marine fish. Demand for fins and meat causing significant population declines.

Shark Advocates

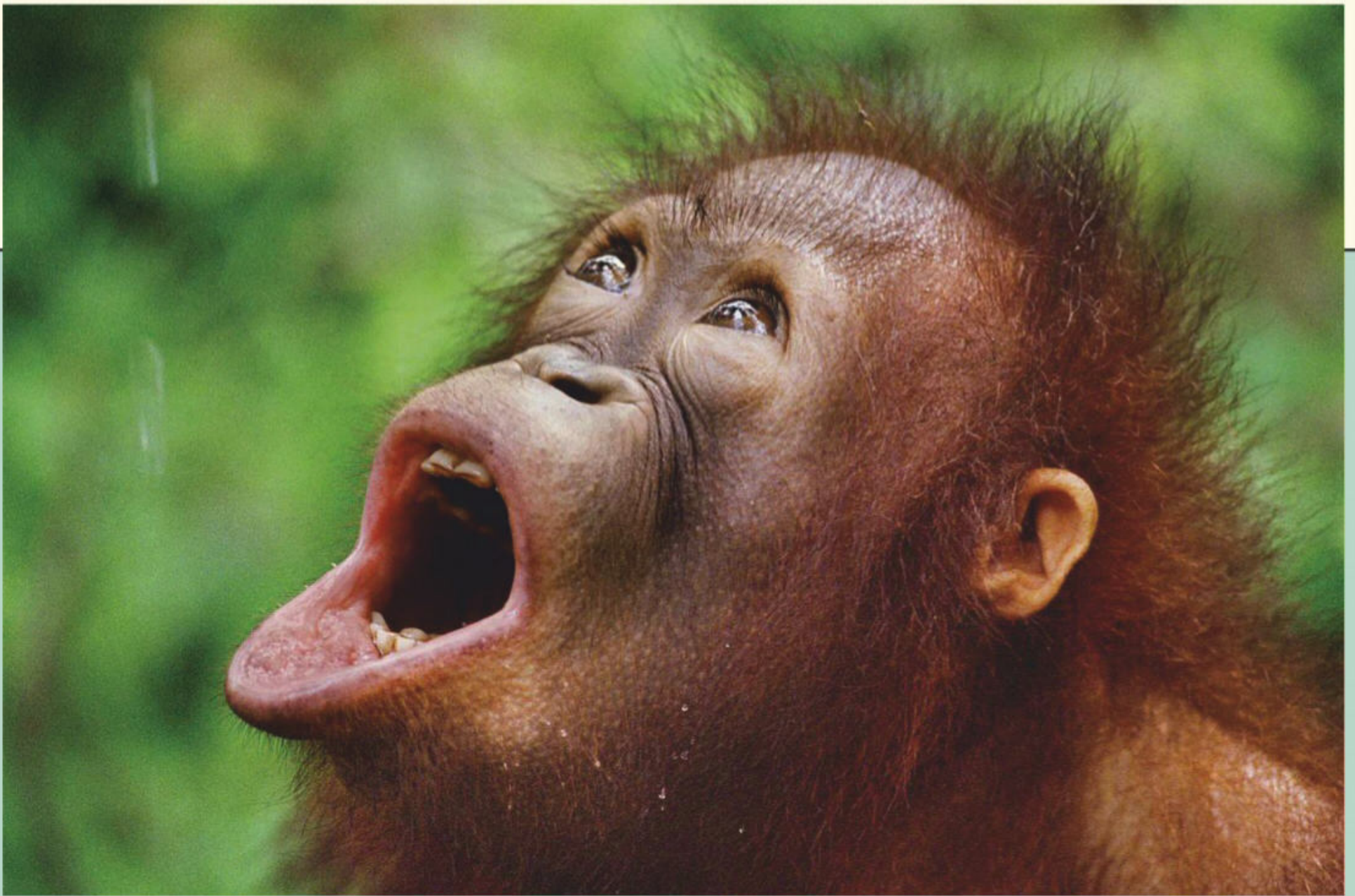
@SharkAdvocates

#RhinoRays are now the world's most endangered marine fish. Most fisheries that take them are poorly monitored, essentially unregulated and increasingly intense. Immediate protections are needed to prevent extinction.

Jess Cramp

@jessadwater

This is not a happy #flatsharkfriday. @IUCNRedList announced that #RhinoRays are the most threatened group of marine fishes in the world due to overfishing. We need better fisheries mgmt + MPAs NOW or these could go extinct. I just saw my first shovelnose ray last week.



CONSERVATION

Orangutan numbers recover in sustainably managed forests

But the primates still struggle in areas with palm oil plantations

An airborne survey of endangered orangutans in Sabah, the Malaysian state in the northeast of Borneo, has found that populations have stabilised within well-managed forests but are still in decline in areas with extensive palm oil plantations. The study was carried out by the World Wide Fund for Nature and is the biggest, most comprehensive survey of orangutans in Borneo to date. The large areas of lowland forest in Sabah is the ideal habitat for orangutans. However, over the past 50 years extensive logging and land clearance for agriculture has led to a drastic decline in their numbers.

The researchers surveyed an area almost 5,500km wide. Based on the number of tree-borne nests counted, they estimate that there are almost 10,000 orangutans living in the area. This includes more than 1,500 previously undiscovered animals spread out in small widely dispersed groups.

The bulk of the orangutans, around 5,550, were found living within sustainably managed forests or in the central uplands away from the loggers. The numbers in this area have



“Conservation efforts are proving successful”

remained stable since 2002, suggesting that conservation efforts are proving successful. In contrast, orangutan numbers in forests surrounded by extensive areas of palm oil plantations have fallen by as much as 30 per cent.

“A recent survey on orangutan populations in Sabah, northeast Borneo showed a mixed picture from different regions,” said the World Wide Fund for Nature’s Donna Simon. “However, overall the research shows that they have maintained the same numbers over the last 15 years and can remain so as long as proper conservation management measures continue to be put in place.”

DINNERTIME SUMS HELP WITH MATHS TESTS

Children whose parents discuss maths problems at the dinner table score better on tests in secondary school, new research has found. The study, which involved over 200 German children, saw that having books around the house, reading to pre-school students and doing maths problems together all contributed to an improved performance at ages 12 and 13. Early exposure to books and language skills didn't just improve students' reading abilities – their outcomes in numeracy also improved.

**In numbers**

10 MINUTES

The time it took for college students' levels of cortisol, a major stress hormone, to drop after interacting with dogs and cats, in a study carried out at Washington State University.

20

The number of moves it took a robot built by researchers at the University of California to solve a Rubik's Cube. It typically takes well-practised humans around 50 moves.

151 DAYS

The time it takes the asteroid 2019 LF6 to orbit the Sun, the shortest orbital period ever discovered.

NEUROSCIENCE

Our brains are tuned to hear music

Human brains are uniquely suited to hearing music, a new study suggests. Compared to macaque monkeys, humans respond much more strongly to sounds with a musical pitch, and prefer those to

× **“Humans respond more strongly to sounds with a musical pitch”**

sounds without a pitch. Our use of language and love of music could be behind these differences.

The team, based at the National Institute of Neurological Disorders and Stroke in Maryland, US,

studied the differences in how humans and macaques hear the world. “We found that a certain region of our brains has a stronger preference for sounds with pitch than macaque monkey brains,” said senior author Dr Bevil Conway.

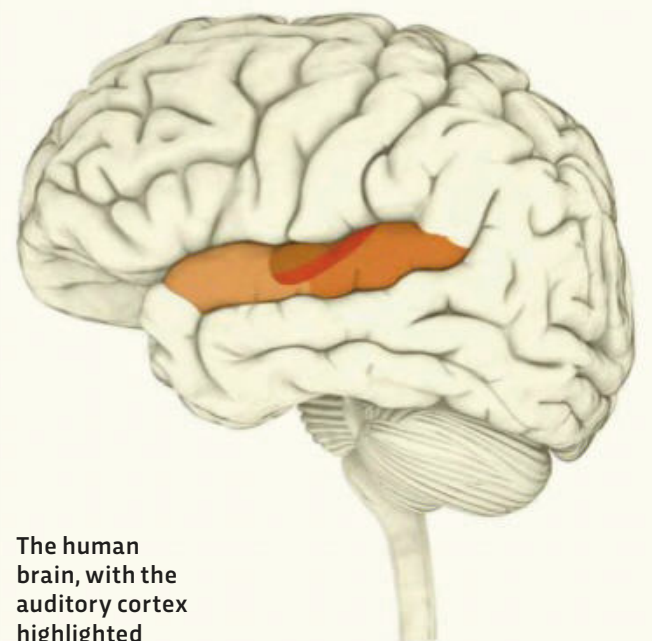
The area of the brain that processes sounds is called the auditory cortex. By studying the activity of the auditory cortex in a non-invasive brain scan, the team could measure how strongly the brain responded to certain sounds.

The sounds were split into two types: noise without pitch, and pitch without noise. Specifically, ‘noise’ is a sound containing lots of different frequencies within a particular range, like the ‘fuzzy’ sound of an untuned radio. Regular human speech and macaque calls have both a pitch and a noise component. To compare how humans and macaques

responded to each type of sound, the team first played the participants a series of pure tones followed by a series of noises made up of similar frequencies.

In humans, the auditory cortex lit up much more brightly when the tones were played, compared to the noises. However, macaques showed barely any difference in how they responded to these two sounds.

“These results suggest the macaque monkey may experience music and other sounds differently,” said Conway. “In contrast, the macaque’s experience of the visual world is probably very similar to our own. It makes one wonder what kind of sounds our evolutionary ancestors experienced. The results raise the possibility that these sounds, which are embedded in speech and music, may have shaped the basic organisation of the human brain. Since we rely so heavily on speech to communicate, and music is culturally important, our brains evolved to accommodate these.”



The human brain, with the auditory cortex highlighted



HEALTH

Premature birth affects relationships in adulthood

Adults who were born following a gestation of less than 37 weeks have lower chances of forming romantic relationships, or having children, compared with those who were born full-term at 40 weeks, according to research by psychologists at the University of Warwick.

The study, which pulled together the results from 4.4 million adults, found that those who were born premature are 28 per cent less likely to form romantic relationships and 22 per cent less likely to become parents than adults who were born full-term. They were also 2.3 times less likely to ever have sex. Adults who were born extremely early, before 32 weeks, have even worse chances.

Other studies have suggested that premature birth is linked with being shy, withdrawn and less inclined to risky behaviour, which is why people who were born early may end up socially excluded or struggling to form relationships.

“The finding that adults who were born pre-term [early] are less likely to have a partner, to have sex and become parents does not appear to be explained by a higher rate of disability. Rather, pre-term born children have been previously found to have poorer social interactions in childhood that make it harder for them to master social transitions such as finding a partner, which in turn is proven to boost your wellbeing,” said Dr Marina Goulart de Mendonça, who took part in the research.

The researchers say that as premature children tend to be more withdrawn, it is especially important for parents and teachers to encourage kids to build friendships, as this will help them to develop their social skills. But take heart: despite pre-term adults having fewer close relationships, the friendships they do form are just as good as those of full-term adults.

They did what?

Seals trained to sing

WHAT DID THEY DO?

Three juvenile grey seals were taught to copy human speech sounds and simple melodies such as *Twinkle, Twinkle, Little Star* by researchers at the University of St Andrews.

WHAT DID THEY FIND?

All three seals were able to mimic some human sounds but one female, named Zola, proved to be the Beyoncé of the group. She was able to sing recognisable versions of several songs, including *Twinkle, Twinkle* and the *Star Wars* theme tune. “Copies were not perfect,” said lead researcher Dr Amanda Stansbury. “But given that these are not typical seal sounds, it is pretty impressive. Our study really demonstrates how flexible seal vocalisations are.”

WHY DID THEY DO THAT?

By studying how other mammals learn to produce ‘human’ sounds, it is thought that we can discover more about our own speech-related development and disorders. The researchers were particularly interested in ‘formants’: the particular vibrations of air inside the vocal tract that humans use to make vowel sounds. Non-human primates are limited in their ability to change formants, whereas pinnipeds – marine mammals that include seals, sea lions and walruses – have a similar way of producing vocal sounds to humans. Formants are an important part of the way we communicate, and studying non-human learning of formants can help us better understand the evolution of complex communication.



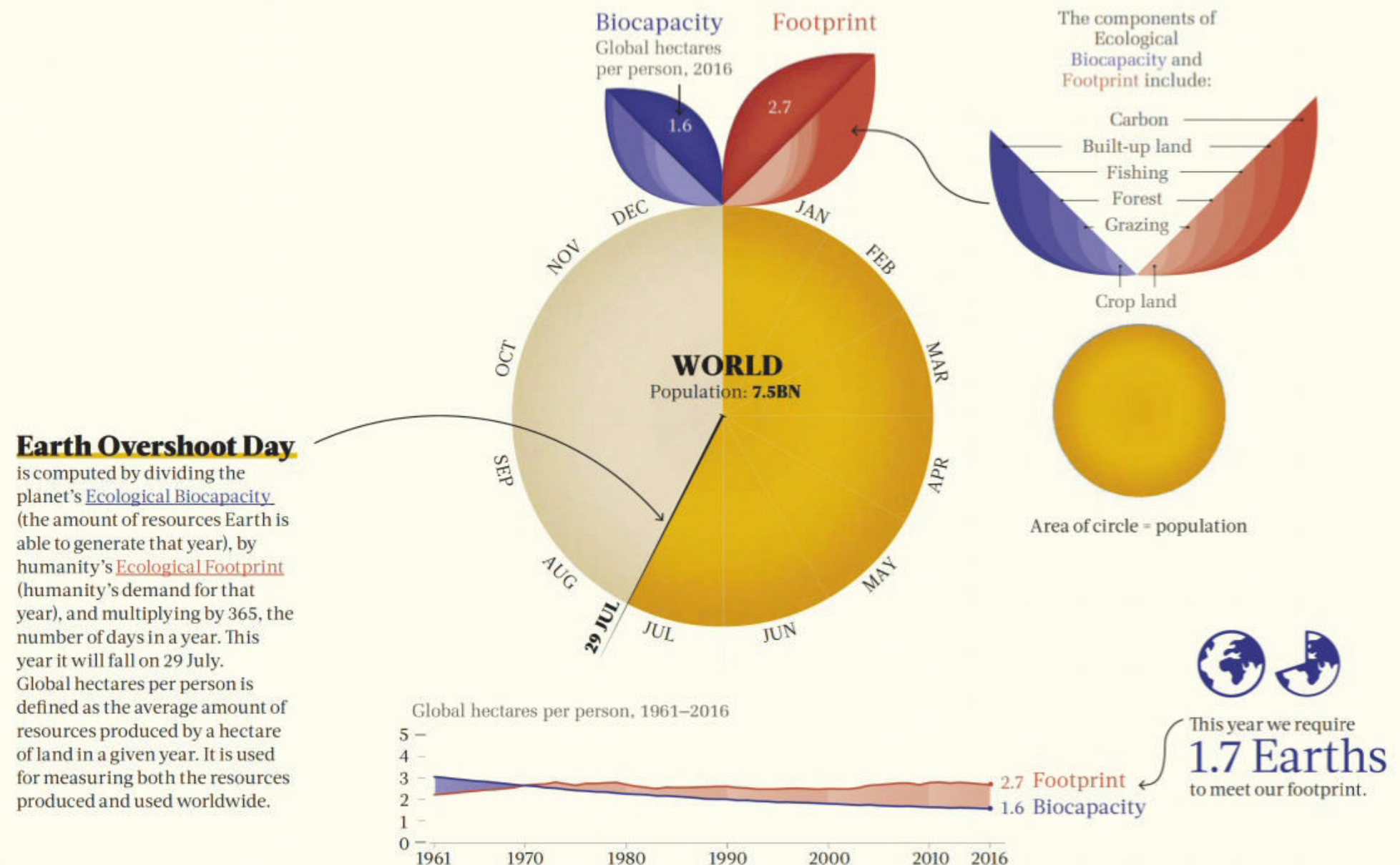
Data crunch

EARTH OVERSHOOT DAY

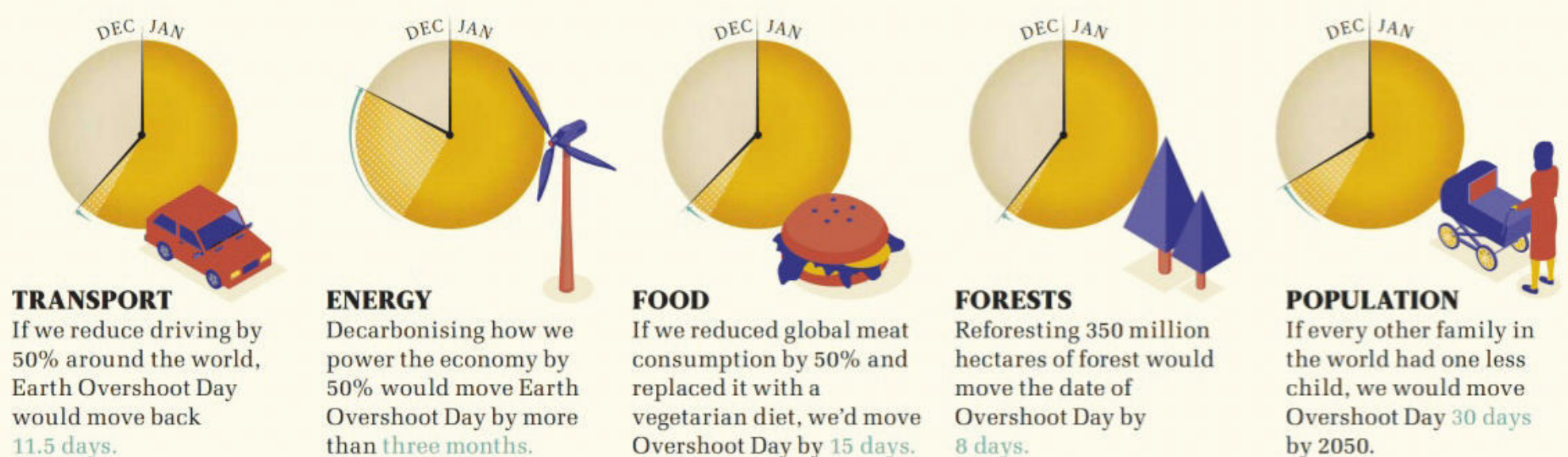
SOURCE: GLOBAL FOOTPRINT NETWORK, 2019 NATIONAL FOOTPRINT ACCOUNTS

Earth Overshoot Day marks the date when the human race's use of ecological resources – fish and plants, for instance – and services exceed the amount the planet is able to produce in a given year. It is calculated every year by the Global Footprint Network as a means of highlighting the growing need for more responsible management of the Earth's natural resources. This year it was calculated to land on 29 July meaning we would currently need 1.75 planet's worth of resources to meet demands.

INFOGRAPHIC BY VALENTINA D'EFILIPPO



If all of the following **solutions** were implemented together, we would no longer be in overshoot:



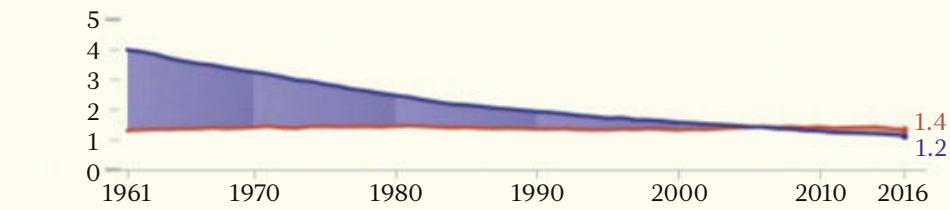
AFRICA

Population: **1.2BN**

Number of regions needed to avoid overshoot: **1.2**

Although it consumes more than what nature regenerates within its regional boundaries

Africa is the only region not in overshoot, because its [Ecological Footprint](#) per capita is lower than the per capita [Biocapacity of the world](#).

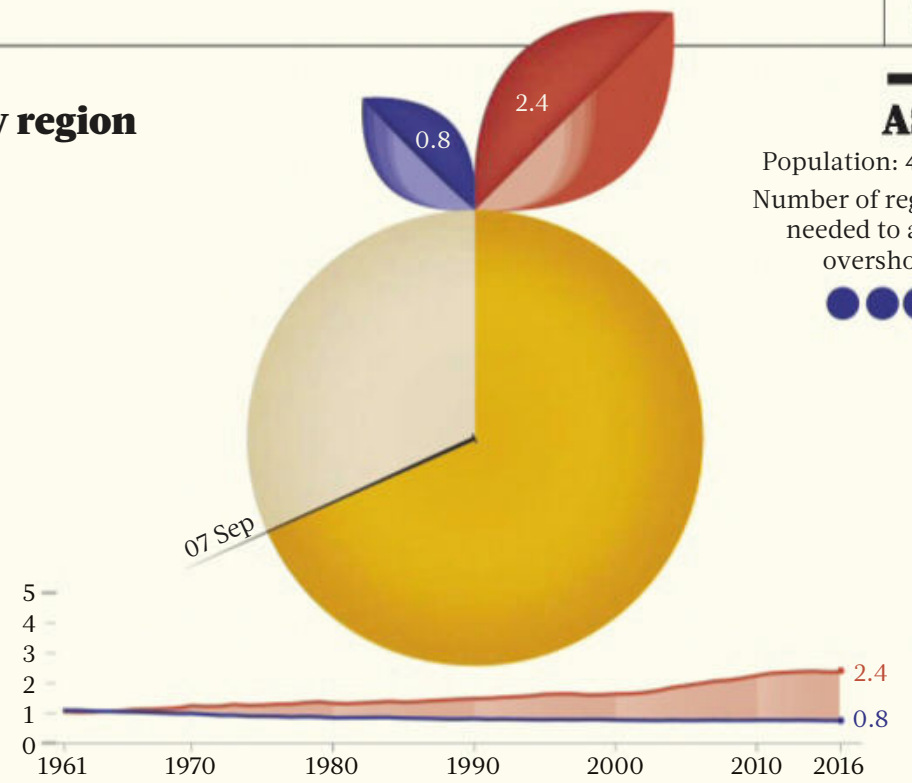


Breakdown by region

ASIA

Population: **4.5BN**

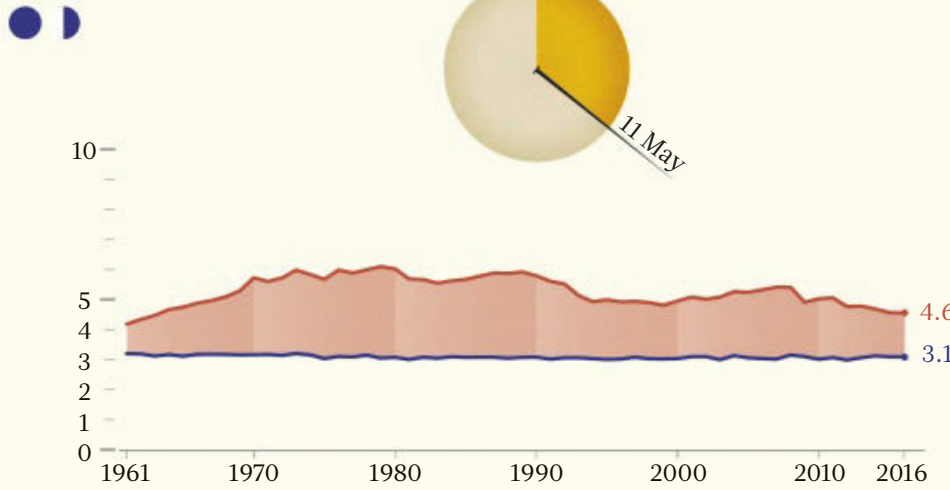
Number of regions needed to avoid overshoot **3.1**



EUROPE

Population: **741M**

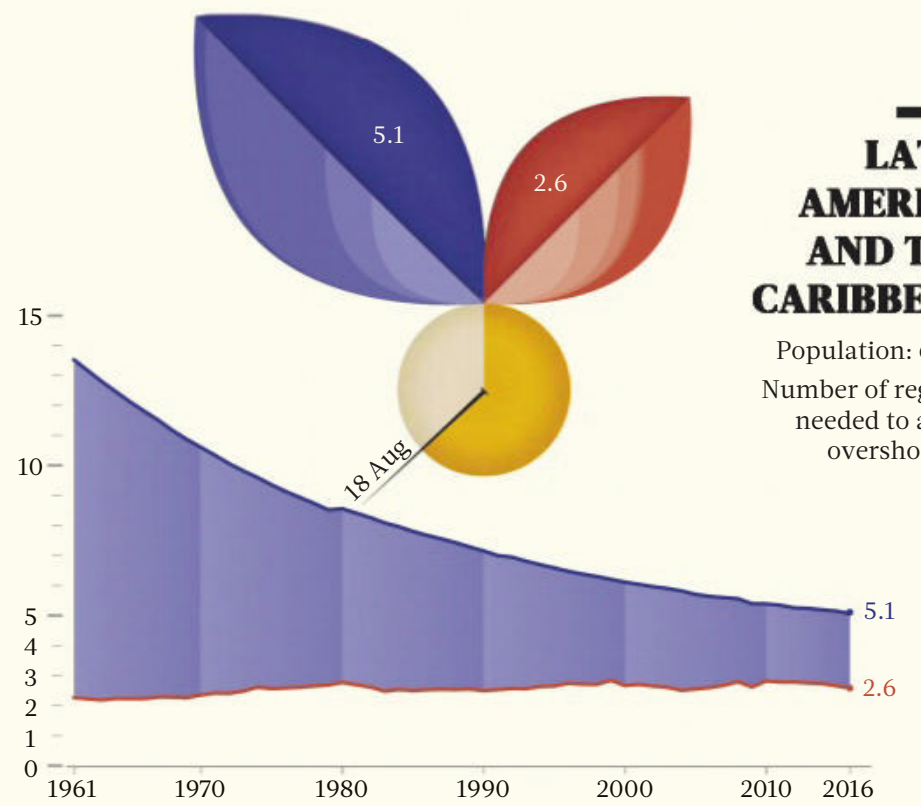
Number of regions needed to avoid overshoot **1.5**



LATIN AMERICA AND THE CARIBBEAN

Population: **639M**

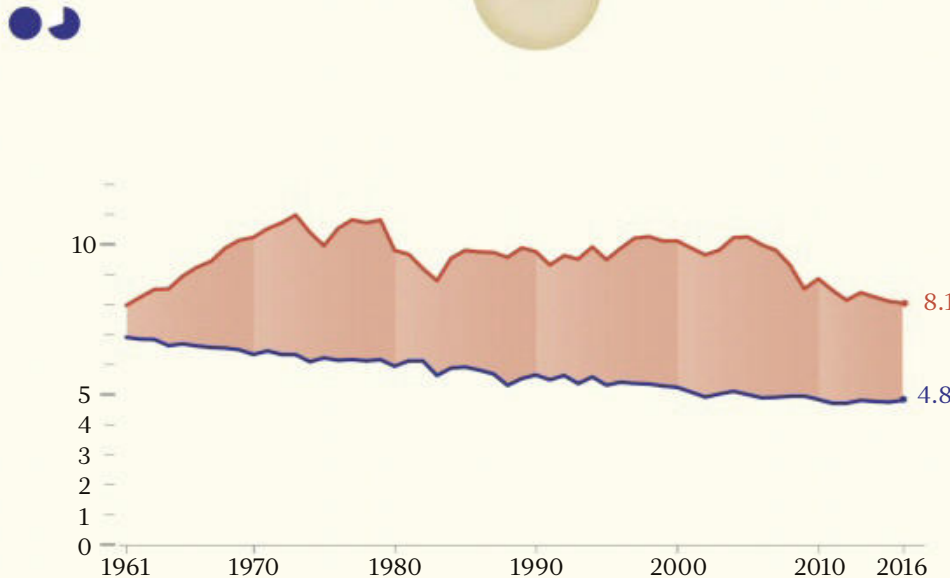
Number of regions needed to avoid overshoot **0.5**



NORTH AMERICA

Population: **359M**

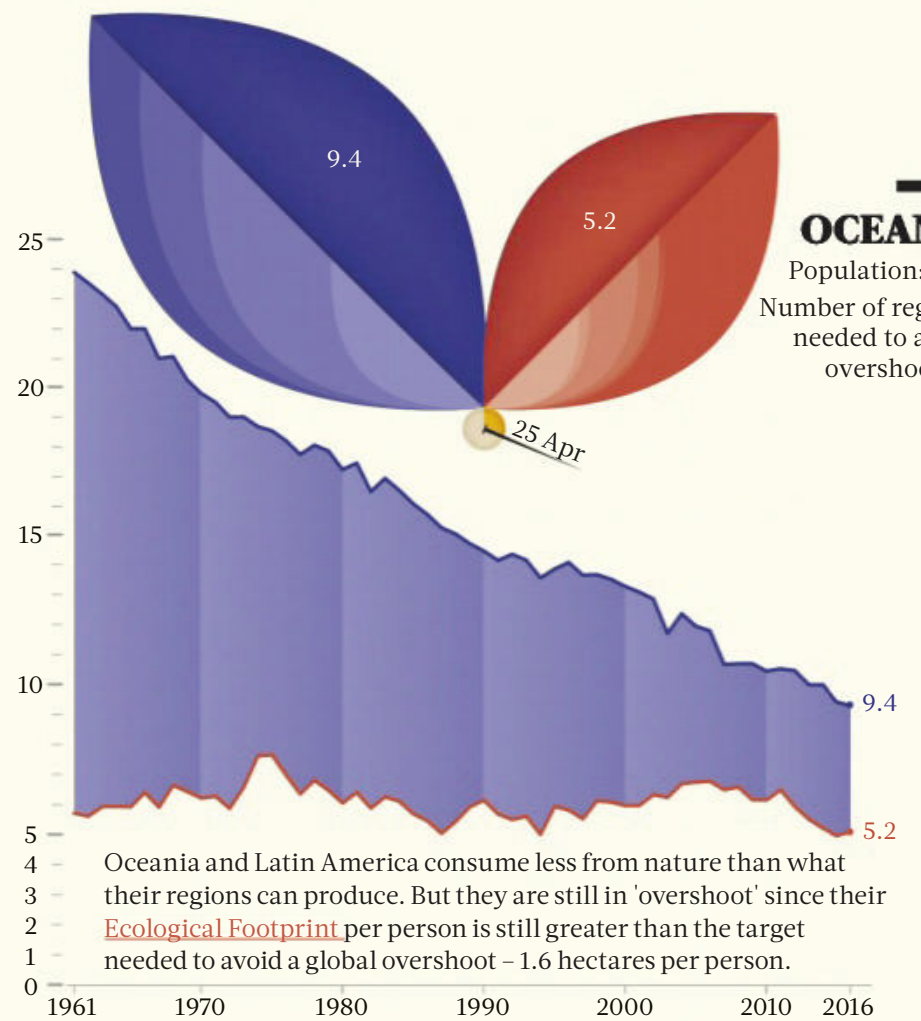
Number of regions needed to avoid overshoot **1.7**



OCEANIA

Population: **40M**

Number of regions needed to avoid overshoot **0.5**



Oceania and Latin America consume less from nature than what their regions can produce. But they are still in 'overshoot' since their [Ecological Footprint](#) per person is still greater than the target needed to avoid a global overshoot – 1.6 hectares per person.

Primer

Neuralink

WITH TESLA AND SPACE X, ELON MUSK MADE ELECTRIC CARS AND PRIVATE SPACEFLIGHT UBIQUITOUS. NOW, HE HOPES HE CAN DO THE SAME FOR MIND-MACHINE INTERFACES...

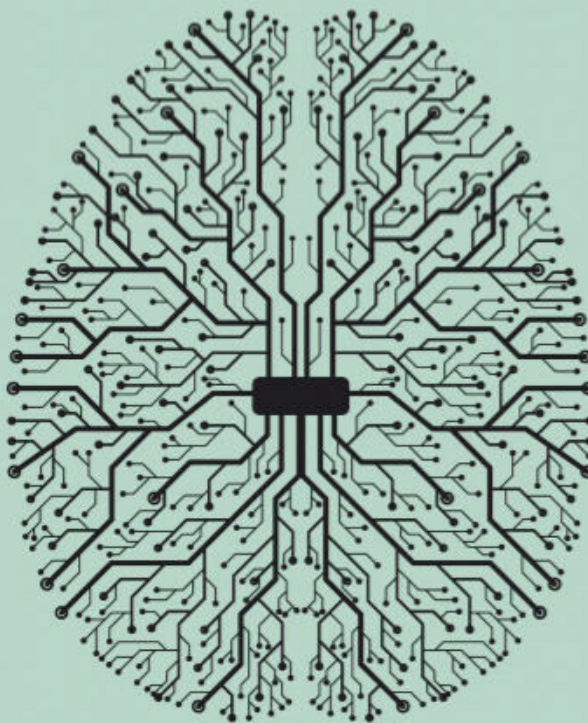
WHAT IS NEURALINK?

Elon Musk wants to control machines with just the power of thought. To that end, last month Musk and his team revealed that they had developed ultrafine ‘threads’ that can be woven into your brain to listen in on your neurons. The company has also built a robot that can perform the delicate surgery, under the supervision of a neurosurgeon. When the company was first launched in 2016, Musk said he wanted to help humans compete in a world where artificial intelligence had surpassed them – to give us more ‘bandwidth’. But with this new announcement the researchers have turned their attention to helping those with brain-related disorders.

HOW DOES IT WORK?

The N1, a 4mm-square chip, is implanted into the skull. Attached to the chip are wires thinner than a human hair, which reach out into the brain. These threads are placed close to important parts of the brain and are able to detect messages as they are relayed between neurons, recording each impulse and stimulating their own. Neuralink says the N1 is able to connect with 1,000 different brain cells, and that a patient might have as many as 10 N1 chips implanted.

The chips connect wirelessly to a wearable device that hooks over the



“What are the ethics behind monitoring someone’s every thought, deed and emotion?”

user’s ear, much like a hearing aid, and contains a Bluetooth radio and a battery. Neuralink says the first devices will be implanted via traditional neurosurgery, but eventually the chips will be inserted safely and virtually painlessly through small incisions by a robot surgeon.

WHAT KIND OF CONDITIONS COULD BE TREATED USING THIS TECHNOLOGY?

The technology could help with neurological disorders, which are rooted in the inability of the brain to connect with nerves around the body. These include epilepsy and Parkinson’s disease, but also paraplegia and quadriplegia following injuries to spinal nerves.

DOES IT HAVE TO BE STUCK INSIDE MY BRAIN?

Unfortunately, the technology needs to be close to each nerve in order to pick up signals – anything further than 60 microns wouldn’t be able to detect individual impulses (1 micron = 0.001mm).

WHAT ARE THE RISKS?

Neuralink will need to learn from the successes (and failures) of existing brain-computer interface technologies. The threads connecting electrodes to the chip need to be flexible, to minimise the damage to surrounding brain tissue. And if this technology is to be given to patients with pre-existing conditions, there are also risks associated with operating on those whose immune systems may be compromised.

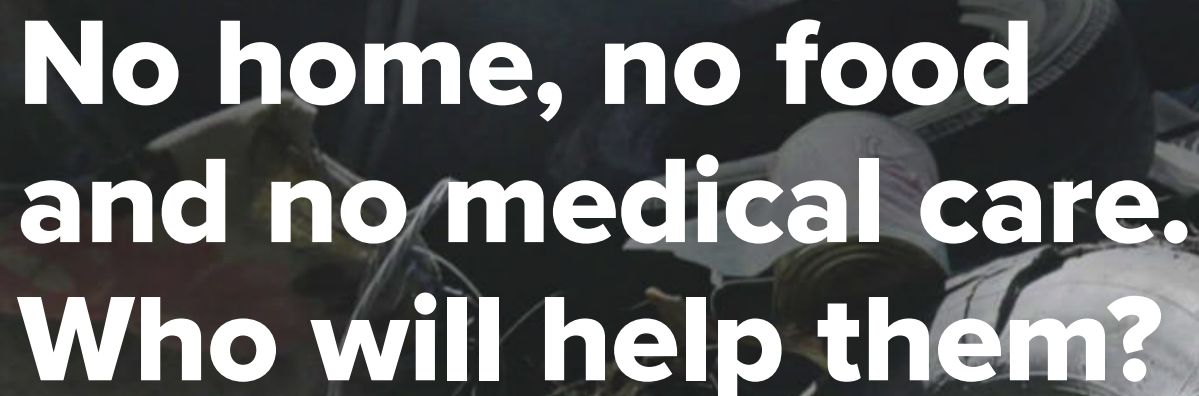
Musk reassured the audience that implanting the device would be as safe as having laser eye surgery, but the company is yet to seek FDA approval, which it will need to market the device.

There aren’t just health risks, either: society will need to consider what to do with the data recorded by the N1. What are the ethics behind monitoring someone’s every thought, deed and emotion?

SO WHEN COULD IT BECOME A REALITY?

Musk hopes for human studies to begin as early as 2020, a date some say is wildly optimistic. At the launch, Neuralink’s CEO Max Hodak stated that the first patients would be those with quadriplegia due to spinal cord injuries. These patients will have four chips implanted, connecting with up to 4,000 different neurons.

The benefits extend beyond the disabled. Musk hopes that the technology will become commonplace, turning the humans into cyborg beings that can achieve a symbiosis with artificial intelligence – something he believes will be essential to the survival of our species.



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REF AVE10B

The scientific guide to...

THE HAJJ

The Hajj is an annual pilgrimage to Mecca in Saudi Arabia, the holiest place on earth for Muslims. This year, it runs from 9 to 14 August. More than two million pilgrims are expected to congregate, making it one of the largest gatherings of humans in the world. Scientific health advice is thin on the ground, so A&E doctor and BBC presenter Saleyha Ahsan offers her views

How physically fit do you need to be?

To really embrace the journey and help you complete Hajj safely, preparation is key. Spend as much time on physical preparation as you do on spiritual preparation. The former will support the latter. As soon as you know you are going on Hajj, start spending time on your feet. Being 'walking fit' is important. Take the stairs instead of the lift, walk to work or at least some of the way, and do the school run by foot. But don't worry, there's no need to embark on marathon-like training.

What about people with preexisting medical conditions?

Dr Imran Zia, an emergency medicine consultant from London who has worked as a Hajj doctor for 11 years and advises for the British Council of Hajj, recommends those with existing health problems carry a document detailing their hospital, consultant, contact information, the name of their conditions, any medication they take, and their NHS number.

Do I need to wear any special clothing?

Having the right footwear for long days walking in hot, dusty terrain is essential.

Sensible walking shoes with socks are a good place to start. Some people opt for rugged terrain sandals which also work. The important thing is to buy them in advance and break them in. Don't wait until you are in Mecca to take them out of the box. You are just inviting blisters! All the best prep in the world might still not prevent you getting blisters and walking long distances in the heat will leave you susceptible. Although it is better to leave blisters intact in their own sterile fluid bubble, if walking is painful, speak to a medic. They may opt to remove the top layer of skin from a blister, clean and dress the area. Change the dressing daily to avoid infection. If it's a small blister, cover it with gauze and apply a firm plaster on top. Don't forget to take oral painkillers to help with the pain.

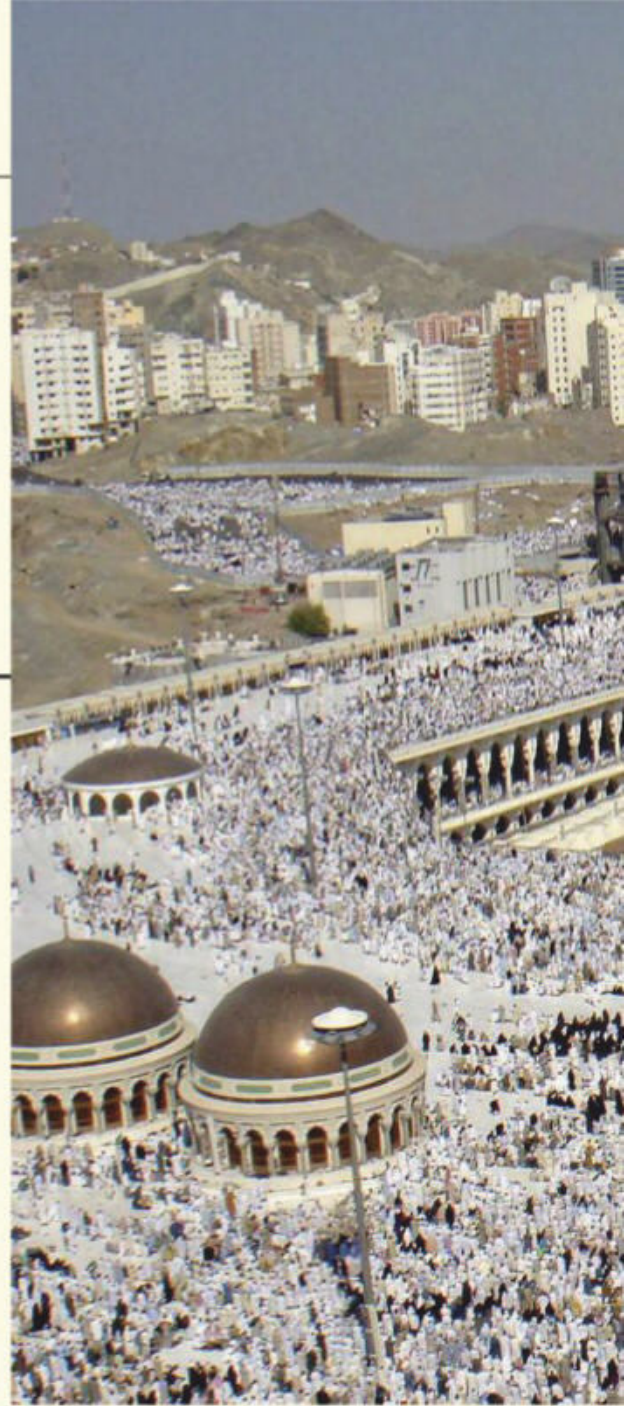
Heat, moisture, sweat and friction can lead to chafing of the skin on the inner thighs. To prevent it, avoid walking in midday heat and apply petroleum jelly or anti-chafing cream between the upper thighs. If chafed, apply lubrication, take painkillers, and rest. If the area becomes blistered, hot, painful and swollen, seek medical help.

How about vaccinations?

Every pilgrim must have received the meningococcal ACWY vaccine, complete with certificate of immunisation. No one gets into Saudi Arabia for Hajj without it. You can either get this from your GP or a pharmacy. Zia recommends pilgrims should get several other vaccinations. Chances are you may already have some of these, so get an update from your GP. All pilgrims aged 65 or over and those suffering from asthma, COPD, heart, liver or kidney disease, diabetes and HIV, should also be immunised against influenza and pneumococcus.

Are there any special considerations for women?

One of the predominate worries on Hajj for women centres on their period. Certain stages of the pilgrimage require



ALAMYX2



LEFT: The Hajj brings more than two million Muslims to Mecca each year

BELOW LEFT: Long walks, blazing heat and fasting can cause problems for some pilgrims



a woman to be period-free. There are several safe, short-term interventions that female pilgrims should discuss with their GP early in their prep.

How do I protect myself against infections?

There's nothing worse than diarrhoea and vomiting, especially when travelling. Ensure you always eat freshly prepared food and make sure any meat is cooked thoroughly. Avoid street food, salads and uncooked vegetables which may have been washed in contaminated water. Only drink sealed bottled water – ZamZam water is safe to drink. (ZamZam water comes from a holy well in Mecca.) Overcrowded facilities contribute to the spread of infectious diseases, including the infamous Hajj cough. It affects over 60 per cent of pilgrims and the sound of coughing soon becomes part of the soundtrack of Hajj. Get the flu and pneumonia jabs before you travel and follow simple hygiene measures – wash your hands regularly with hand-cleansing gel, throw tissues in bins after use, and don't share towels, cutlery or cups.

What should I do if I get dehydrated?

Despite signage with plenty of water

stops, pilgrims still fail to keep hydrated. We need between two to three litres of fluids daily in normal conditions. Walking in high temperatures can lead to significant fluid loss in sweat, which means we need to replace that. Keep a water bottle close at hand and drink small amounts regularly, and always wear plenty of sunscreen. Don't wait to become thirsty before you drink. Fruit juices can help as they provide fluid, nutrients and sugar.

If you experience headaches, thirst, dizziness, nausea, vomiting or muscle cramps you may be dehydrated. Get into shade, drink water with diluted rehydration salts or diluted fruit juice, and get some rest.

If you are suffering from confusion and agitation, you stop sweating, you have hot and dry skin, and you experience a loss of consciousness, you may be suffering from heat stroke. This is a life-threatening medical emergency and needs immediate hospital attention.

What should I do when I return home?

Most people have nothing more than the Hajj cough to recover from on their return home, but it can take a couple of weeks for the virus to clear.

Some may have aching muscles and feet. If you've been on a flight with long periods of immobility, make sure you don't confuse a swollen, tender, red leg for simple muscular pain. If you notice pain in your calf and the affected leg is bigger than the other, seek immediate medical help as this might be a blood clot. To protect yourself when flying, walk regularly in the plane aisles and do leg exercises when sitting.

A few days of post Hajj recovery will likely mean catching up on sleep, reflecting on what you've just achieved, and letting it sink in that you are now officially a Hajji.

by **DR SALEYHA AHSAN**

Saleyha is an A&E doctor in Bangor, North Wales. She presents BBC programmes like Trust Me, I'm A Doctor and Panorama.



Bob Ward Grantham Research Institute

Horizons

Can planting billions of trees help tackle climate change?

A recent study published by researchers at the Federal Institute of Technology in Zurich suggests that planting at least one trillion trees around the world could capture two-thirds of the carbon pumped into the atmosphere due to human activity

WHY ARE TREES SO VITAL FOR THE EARTH'S ATMOSPHERE?

They're vital because trees, like all plants, absorb carbon dioxide from the atmosphere and produce oxygen. So, given that the problem that we have is the growth in the concentration of carbon dioxide and other greenhouse gases in the atmosphere, trees are a vital part of it.

The loss of trees that we've experienced over the past few decades and centuries has been a major contributor to creating the problem we have. So planting new vegetation and new trees is an essential part of the solution, and we certainly have to stop destroying forest areas. The main message is that planting forests is an important contribution to effort against global warming – but we have to be careful not to exaggerate what we can do, and it's certainly not a 'get out of jail free' card. We will still have to stop emitting carbon dioxide. We can't just continue as

we are and plant lots of trees to make up for it – that's not going to work.

WHAT SORT OF IMPACT HAS HUMAN ACTIVITY HAD ON CARBON LEVELS?

The concentration of carbon dioxide, which is the main greenhouse gas, before industrialisation started was around 280 parts per million. It is now over 410 parts per million.

HOW DO WE CALCULATE THAT FIGURE?

Well, the main way is that you can measure the isotopes in carbon dioxide, and you can see that the increase is due to the presence of carbon dioxide with carbon isotopes in it that can only have occurred from the burning of fossil fuels. Naturally occurring carbon dioxide and the carbon dioxide you produce from burning fossil fuel have different isotopes, so that's how we know.

And indeed, if you look at where all this extra carbon dioxide could have come from, the *only* way you would be able to produce it is by burning fossil fuels anyway. There's no other major source. Some people have suggested that you also get carbon dioxide from volcanoes, but we know that just doesn't happen at a scale that could explain the huge increase in carbon dioxide levels that we've seen in the atmosphere.

And we measure the pre-industrial carbon dioxide levels from analysing the bubbles in ice cores. Where ice forms in the major ice caps in Antarctica and Greenland, you can drill down and, essentially, you can calculate when each level of ice formed. When ice forms, it traps little bubbles of air, the air at that time in it. So if you go back in now and extract these ice cores, you can then analyse the air in these bubbles and calculate what the concentration of what each gas is, and that's how we know it used to be about 280 parts per million.

IN ORDER TO CALCULATE THE AREAS OF LAND MASSES THAT COULD BE USED TO



×

“We absolutely should be planting more trees right now, but it will not get us anywhere near as close to solving the problem as this paper calculated”

GETTY IMAGES



PLANT TREES, THE ZURICH STUDY MAKES AN ESTIMATE OF HOW MUCH CARBON DIOXIDE A GIVEN TREE CAN ABSORB, AND MULTIPLIES THEM. THAT SEEMS A BIT SIMPLISTIC?

Yes, they've over-simplified the calculation and ended up with an inaccurate estimate because they've assumed that if you started planting more trees, then that would simply remove carbon dioxide from the atmosphere.

But we know that carbon dioxide is also absorbed by seawater and soils, and that the concentrations are in equilibrium with each other. So when we emit carbon dioxide by the burning of fossil fuels, some of it goes into the atmosphere, some goes into the ocean, and some goes into the land. Equally, if you start extracting it from the atmosphere, you will get a flow of some carbon dioxide coming out of the oceans and the land into the atmosphere. Not all of the carbon dioxide you remove from the atmosphere will

result in a straightforward reduction of concentrations. So with that estimate you could essentially compensate for two-thirds of the carbon dioxide that's already been emitted, they only counted the carbon dioxide that had gone into the atmosphere – they either forgot or overlooked the carbon dioxide that's been emitted and gone into the oceans and the land, and that would go back into the atmosphere if you started removing it.

HOW ABOUT THE AREAS OF LAND THAT THEY HAVE IDENTIFIED?

Large parts of the areas that they're suggesting could be forested probably aren't suitable for growing forests in, often because soils are not right. There are also large areas in Northern Canada and Siberia where if you plant trees you end up with, ironically, with an impact that might make climate change worse, because one of the other things that's causing the Earth to warm is something

called albedo. What happens is that when you have white surfaces, like ice, a lot of sunlight is reflected back out into the atmosphere, preventing warming. Dark surfaces tend to absorb more of the sunlight and cause more warming. And so, if you start planting trees, they're relatively dark compared to the ice that's there now, and you might end up causing a bit more of a warming effect by doing it, which would not be helpful.

We absolutely should be planting more trees right now but, because of these simplifications, it will not get us anywhere near as close to solving the problem as this paper suggested.

BOB WARD

Bob is the policy and communications director for the Grantham Research Institute on Climate Change and the Environment. Interviewed by BBC Science Focus commissioning editor Jason Goodyer

NEVER TOO OLD TO LEARN

Learning multiple skills at once can give older people a mental boost, a study at the University of California, Riverside has found. Participants aged 58-86 enrolled in three to five classes (such as Spanish, photography, IT skills, art and music composition) totalling about 15 hours per week. After six weeks, the participants showed improvements in their memory and cognition skills, putting them on a par with those 30 years younger.



ZOOLOGY

Genetic secrets of sex-changing fish discovered

Around 500 species of fish are known to undergo one of the most startling transformations in the natural world – the complete reversal of sex. Now, a study carried out at the University of Otago, New Zealand on bluehead wrasses, a small-bodied fish that lives in coral reefs in the Caribbean, has found out how they do it.

Most bluehead wrasses begin life as females, but when the dominant male is lost from a social group, the largest female transforms into a fertile male in as little as 10 days. They begin this transformation within minutes of the male's departure, first changing colour and displaying male-like behaviours. Their ovaries then start to regress and fully functional testes grow in their place.

Using the latest genetic approaches, the researchers discovered that the change

is the result of specific genes being 'turned off' in the brain and gonad. The transformation begins when aromatase, a gene responsible for making the female hormone oestrogen, is turned off, though exactly what triggers the aromatase to turn off is not yet known.

"How this stunning transformation works at a genetic level has long been an enigma," said the study's co-lead author Dr Erica Todd. "Our study reveals that sex change involves a complete genetic rewiring of the gonad. We find that genes needed to maintain the ovary are first turned off, and then a new genetic pathway is steadily turned on to promote testis formation."

The amazing transformation also appears to be made possible thanks to changes in cellular 'memory'. As researcher Oscar Ortega-Recalde explained: "In fish and

other vertebrates, including humans, cells use chemical markers on DNA that control gene expression and remember their specific function in the body. Our study is important because it shows that sex change involves profound changes in these chemical marks, for example at the aromatase gene, thus reprogramming cell memory in the gonad towards a male fate."

As many of the genes that are important for sexual development in fish are also important in other animals, the team's discovery could eventually have practical applications for humans.

"Understanding how fish can change sex may tell us more about how complex networks of genes interact to determine and maintain sex, not only in fish but also in vertebrate animals more generally," Todd said.



NATURAL TRANSITIONS



The ability to change sex is surprisingly common in fish species, particularly those, such as clownfish and wrasses, that dwell in a coral habitat.



Adult hens have one developed left ovary, and one undeveloped right ovary. If the left ovary is damaged, the dormant right one can in some cases develop as a testis instead.

In humans, there are several hormone deficiencies that can cause a child to appear female before puberty, but male once puberty has taken place.





Salford, UK

ANTHROPOLOGY

Tuning in to the mystery of Stonehenge

Sound engineers at the University of Salford have created a tiny model of Stonehenge in order to investigate the ancient monument's acoustic properties.

The 157 stones were made by pouring a plaster-polymer mix into individual 3D-printed silicone moulds, which were constructed using highly accurate laser scan data provided by Historic England. The 1:12 scale model is just over 2.5m across and includes representations of many stones that are now missing from the original monument.

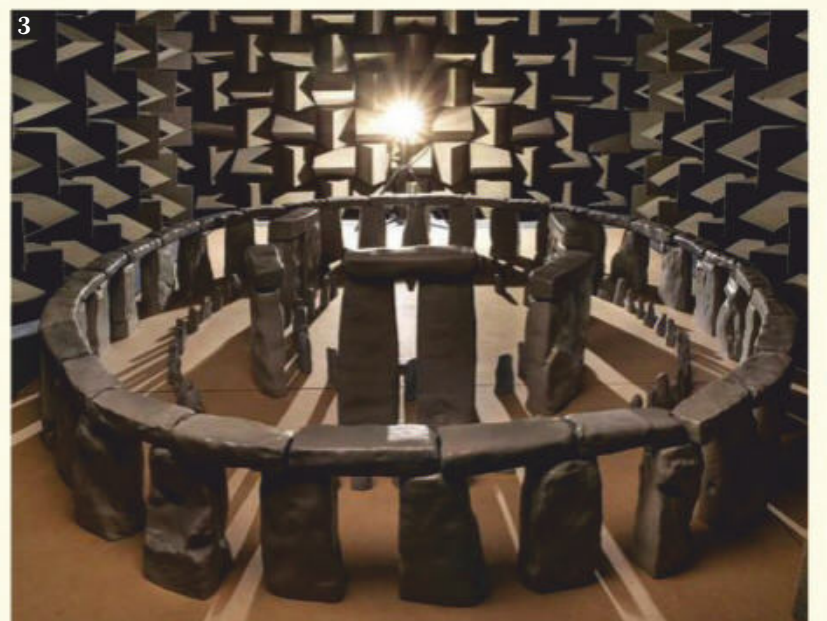
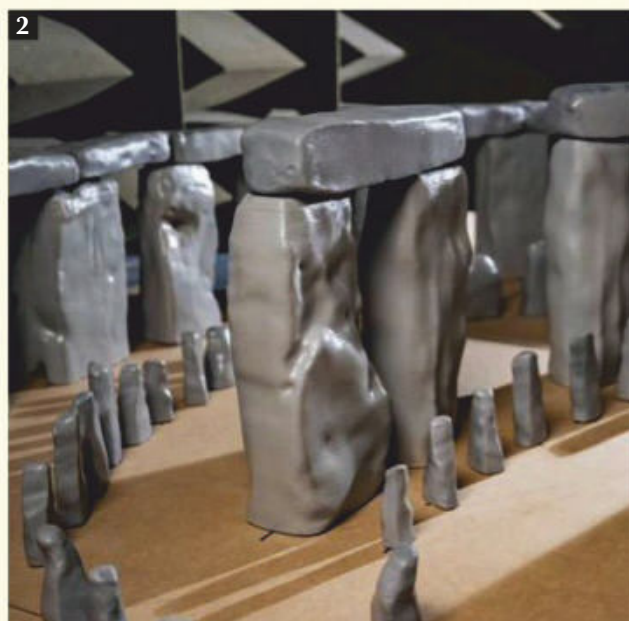
Prof Trevor Cox and his team created the model to test its acoustic properties, in an attempt to shed light on what Stonehenge may have been used for. "There have been very few studies into the sounds created at Stonehenge," said Cox. "We know, for example, that reflections from the stones should have helped to reinforce speech. But by how much? This scale model, which uses archeological mapping techniques to better understand the site's layout, will give us new insights into what our ancestors would have heard in the stone circles."



1. Prof Trevor Cox tested the acoustic properties of the scale model using ultrasonic soundwaves.

2. The 157 stones were carefully positioned to faithfully replicate the structure of the real-life Stonehenge.

3. The completed model was placed into an anechoic chamber for acoustic analysis. The pattern of spikes on the walls are specially designed to completely absorb all sound waves.



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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

REVIEW

LIVE FACIAL RECOGNITION: HOW IS IT USED?

Police forces around the UK are coming under fire for their trials of live facial recognition technology.

What is it?

Live facial recognition (LFR), also known as automatic facial recognition, identifies people in a video in real time, using a set of photographs as a reference. When used in public, cameras scan a crowd and the software highlights any matches between members of the public and the people in their database.

How does it work?

The live video feed is scanned for faces. Each face that is found is then mapped by the software, taking measurements of facial features, such as the distance between the eyes and the length of the jawline, to create a unique set of biometric data. This dataset is then compared to a database of people to be identified; for the police, this database contains people with outstanding warrants. If the system judges the face to be sufficiently similar to someone in its database, this match is highlighted.



As shown in this visualisation, live facial recognition can detect faces within a crowd and takes measurements of features

“Unmatched faces are deleted straight away, and matched images are deleted after 30 days”

Who is using it?

In the UK, the London Metropolitan Police (the Met), the South Wales Police and Leicestershire Police have all trialled the technology in public since 2015. The system was tested at Download Festival in 2015, the Champions League final and Notting Hill Carnival in 2017, among other events, with the Met's final test taking place on 14 February 2019. In these cases, the database consists of photos of people wanted by the police or courts. If the system makes a match, it presents the police with both images, so they can decide whether to stop and speak to the person. Unmatched faces are deleted straight away, and matched images are deleted after 30 days.

Other facial recognition systems are already in use in the UK. In 2004, EU countries began to incorporate biometric data into new ePassports, identifiable by a small, gold camera logo on the front cover. These became available in the UK in 2006, and the microchip embedded in the cover contains both the holder's personal information and photograph. In many airports across the UK and Europe,

as well as Eurostar terminals in Paris and Brussels, travellers can verify their identity with the facial recognition systems in automated ePassport gates in immigration halls.

Trials of facial recognition software were also carried out in three prisons in an attempt to combat drug smuggling. HMP Hull saw a 40 per cent drop in visitors during this time, and a spokesperson for the Ministry of Justice described this as a successful deterrent.

Amazon's facial recognition system, Rekognition, has been tested by police forces in the US, including Orlando Police Department in Florida and Washington County Sheriff's Office in Oregon. It was reported in July that the system had been abandoned in Orlando after 15 months of unsuccessful trials. The FBI and Immigration and Customs Enforcement (ICE) have also used the technology to identify undocumented immigrants from their driving licence photographs.

Is it legal?

Currently, there is no UK regulation regarding facial recognition technology. Though the police trials have been supported by Home Secretary Sajid Javid, he told the BBC that legislation would have to be put in place before it could be used long-term.

The House of Commons Science and Technology Committee published a report in July calling for a moratorium on all facial recognition technology until legislation has been put in place.

Meanwhile, San Francisco and Oakland in California, and Somerville in Massachusetts, have all banned the use of the technology.

How effective is it?

The issues raised by the committee's report include the technology's effectiveness. For example, at the 2017 Champions League final, the facial recognition system highlighted 2,470 matches to individuals on the police's database. Only 173 of these were correct, giving it a 92 per cent error rate. When the Home Office tested the Police National Database's system in 2015, they found that it was half as effective as a human, and a University of Essex study of the Met's system found it to be correct only 19 per cent of the time.

Facial recognition systems also have the potential to be biased. If the database that 'trains' them is predominantly white and male, it will be much more effective at distinguishing white, male faces. The risk is that women and ethnic minorities are much more likely to be falsely identified. A 2019 paper from MIT found that Amazon's Rekognition had a 0 per cent error rate among light-skinned men, which rose to over 30 per cent for dark-skinned women.

Can we stop our biometric data being collected?

The Met's website says that "Anyone can refuse to be scanned; it's not an offence or considered 'obstruction' to actively avoid being scanned." However, the BBC reported in May that one man was fined £90 for disorderly conduct after attempting to cover his face during a trial of the system in East London.

by **SARA RIGBY**

Sara is the online assistant for BBC Science Focus. She has an MPhys in mathematical physics.

DISCOVER MORE

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These police cameras in Essex scanned people's faces and matched them against a database as part of a trial earlier this year



ALAMY, GETTY IMAGES



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Some people claimed that 'Oumuamua was a spacecraft powered by starlight – a solar sail

ANALYSIS

'OUMUAMUA: WHY DID WE THINK IT WAS ALIENS?

New research says that our first interstellar guest was natural. So where did the alien hypothesis come from?

Astronomers spotted 'Oumuamua in October 2017, as it was already on its way out of the Solar System, and scrambled to decipher its secrets before it sped out of sight. It was the first object ever detected to have come from outside of our Solar System. Was our interstellar visitor a comet or an asteroid – or maybe an extraterrestrial

spacecraft? Not long after, the SETI (Search for ExtraTerrestrial Intelligence) Institute's Breakthrough Listen project announced its plan to probe the mysterious object for radio signals, which could hint at alien life. But disappointingly for alien hunters, they came up empty-handed. Now, a year and a half later, the final nail has been driven into the 'alien hypothesis' coffin with a scientific paper titled *The Natural History Of 'Oumuamua*. "For all of the available observations that were made, the best answer that we have is that it was a natural object," says Dr Michele Bannister, one of the paper's authors.

And yet, the idea that aliens could be traversing our Solar System was always tenacious, mostly because 'Oumuamua was completely unlike anything we had seen before. For one thing, its brightness

The odd brightness variations of 'Oumuamua suggest that it could be cigar- or pancake-shaped



“The next time ‘Oumuamua comes, we might be able to have a spacecraft waiting to go visit it”

varied by a factor of 10, like a slow-motion twinkle. This suggests it could be a cigar-shaped object, 10 times longer than it is wide, reflecting more or less light as it tumbles end over end. That’s the familiar image of ‘Oumuamua, but we don’t know for sure what it looks like. Even the most powerful of our telescopes couldn’t resolve its shape beyond a point of brightness. The same glimmer could easily be produced by a pancake shape. Either way, no comet or asteroid in the Solar System has such an extreme ratio of length to width.

Over the short time it was within sight of our telescopes, astronomers grappled with its identity. It looked like an asteroid. It showed no signs of cometary ‘outgassing’, which is the tail of evaporating gas that can be seen as the Sun melts a comet’s ice. But then it accelerated out of the Solar System, faster than could be accounted for by gravity. Various means of explaining this acceleration were floated, including a collision with another object and a combination of magnetism and solar winds, but the most outlandish theory was that it was an alien spacecraft.

In a paper published in the journal *Astrophysical Journal Letters*, Dr Shmuel Bialy and Prof Abraham Loeb, at Harvard University, laid out their logic to suggest that ‘Oumuamua could have been a solar sail of alien origin. Just as the wind filling a ship’s sail is made up of a huge number of air molecules, the tiny impact of each photon of starlight bouncing off a large, thin solar sail could theoretically add up to enough force to power a spacecraft. However, there is a key problem with this theory: the tumbling motion that revealed its extreme shape in the first

TIMELINE

9.9.17

‘Oumuamua reached its closest point to the Sun, a distance of 38 million kilometres.

19.10.17

‘Oumuamua was discovered by the Pan-STARRS1 telescope in Hawaii.

20.11.17

In a paper published by the American Astronomical Society, ‘Oumuamua is confirmed to come from another solar system.

2.1.18

The Hubble Space Telescope captured the last observation of ‘Oumuamua before it passed out of sight.

place. To work effectively as a solar sail, a broad surface needs to be pointing at the Sun. “That hypothesis does not fit with the evidence,” says Bannister, though the reason for its unusual acceleration is still unclear.

So, if ‘Oumuamua is not an alien spacecraft, what is it? When taking into account all the evidence, Bannister says that it becomes clear that it is a planetesimal. “This is a little building block of a planet that started its life around another star and has travelled to us,” she says.

Even if it is a natural phenomenon, the chance to study the first ever object from outside the Solar System is exciting in its own right. “In many ways, this was the gravitational waves moment for people who study how solar systems form and evolve,” says Bannister.

Better yet, we could explore the Solar System’s next visitor in more detail after the launch of the European Space Agency’s Comet Interceptor mission in 2028. Comet Interceptor will park itself far from Earth, waiting to chase an interesting comet or interstellar object. “The next time ‘Oumuamua comes, we might be able to have a spacecraft waiting to go visit it,” says Bannister.

“I’m really, really excited by that. It’s going to be so much fun.”

by SARA RIGBY

Sara is the online assistant for BBC Science Focus. She has an MPhys in mathematical physics.

COMMENT

OBESITY: SHOULD WE COMPARE IT TO SMOKING?

Cancer Research UK's recent campaign compares obesity to smoking as a cause of cancer. Is this a fair comparison?

Controversy, the nirvana of any campaign, brings wide reach and media attention. Cancer Research UK (CRUK) has attracted plenty, with its new ads featuring images of old-fashioned fag packets emblazoned with the simple message 'obesity is a cause of cancer too'.

As well as increasing awareness, CRUK says that the goal is to protect children

The new obesity adverts from Cancer Research UK take inspiration from cigarette packets



against ‘junk’ food adverts by getting the government to commit to a 9pm watershed on TV. However, the new campaign may be doing more harm than good. At the time of writing, more than 11,500 people had signed a petition calling for its end.

Smoking and obesity are fundamentally different: smoking is a behaviour (something people do) whereas obesity is a physical outcome (a measurement of body mass). Both are complex social issues that require good government policies to promote health. But at an individual level, the most effective way to reduce smoking-related cancers is to stop smoking. This abstinence approach is impossible to replicate for obesity. People can’t just stop eating; neither can they simply lose weight. In fact, although short-term weight loss is possible, weight loss trials show that, in the long-term, most people put it back on. This leaves many of us in an unhealthy cycle of yo-yo dieting.

Body weight and size are influenced by many different factors both at a personal level (genetics, psychology) and a societal level (built environment, government policies). For instance, some people are genetically predisposed to have a higher body mass and be more resistant to weight loss than others. This means societal factors affect some people more than others and weight management isn’t the same for everybody.

Regardless, the sight of these cigarette-style posters encourages people to associate the stereotypes of smoking with obesity, in particular, that obesity is the result of irresponsibility. The simple fact is that neither smoking nor obesity are merely outcomes of people making bad choices. In this way, this campaign encourages weight stigma and discrimination. Smoking is considered to be unfairly damaging the health of others, through passive smoking – the same cannot be said for obesity. However, as the ensuing media debate has shown, this comparison encourages the same moral outrage. This creates a hostile environment for people of higher weights.

We’ve all seen media stories that go something like this: a culture of political correctness is allowing fat people to live in denial because people are too afraid of

hurting their feelings with hard truths. This framing is patronising clickbait that masks reality. It’s also counterproductive: numerous studies show weight stigma promotes calorie consumption, exercise avoidance and weight gain. If weight stigma was effective, it would be fair to say the dominant anti-fat culture we already live in would prevent people putting on weight. But it doesn’t. Fear of stigma also stops overweight people going to see healthcare professionals and leads to cancer going undiagnosed. Clearly, this should be a concern for CRUK.

So how could the CRUK campaign be improved? If policy change is the aim and the government is the target, then logically the CRUK campaign should focus on building public pressure to force government action. The campaign should educate the public about how inequality, unemployment and lack of food industry regulation increase the risk of cancer, and encourage people to support social change. Rather than increasing hostility towards people of higher body weights, CRUK should bring people together in a call for positive action.

by DR OLI WILLIAMS, LESLEY GRAY and HELEN WEST

Oli is a fellow of The Healthcare Improvement Studies Institute at King’s College London. Lesley is a senior lecturer in public health at the University of Otago, New Zealand. Helen is a freelance registered dietitian.

X

“These cigarette-style posters encourage people to associate the stereotypes of smoking with obesity”

Cancer Research
UK says ...



Michelle Mitchell,
chief executive of
Cancer Research UK

Obesity is a complex issue, with no single cause or solution.

We’re comparing smoking and obesity to show how government-led change can help people form healthier habits – not to compare tobacco with food. The campaign aims to raise awareness of the link between obesity and cancer, and to bring about policies that make healthy options accessible for everyone, including restricting junk food advertising and price promotions on the most unhealthy products. It isn’t meant to make anyone feel bad about their weight, or to think negatively about people who are overweight or obese. We have adopted many of the World Obesity Federation principles and signed up to the Obesity Health Alliance’s position statement on weight stigma, and continue to engage with experts on these complex issues. While we don’t want to cause offence, we’re spreading an important message – and having run this campaign several times, we’ve surveyed thousands of people with a range of body weights, and 84 per cent agree it’s an important message that needs to be communicated.

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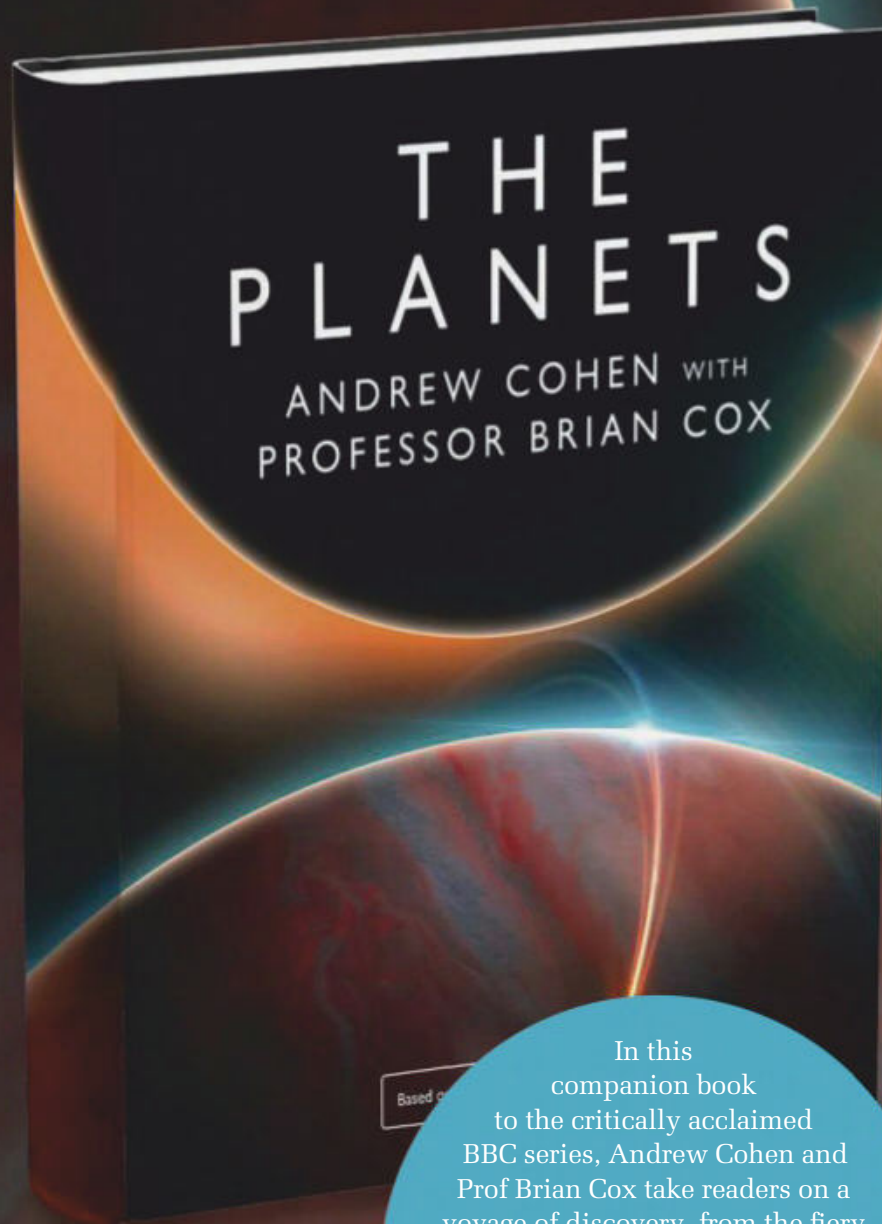
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THE ANIMAL BLINGDOM

While many creatures adapt to blend into their environment, there are some who show no such regard for convention. Here are some of our favourite show-offs from the animal kingdom...

by BEN HOARE

DICEY DANCING

← PEACOCK SPIDER

Jumping spiders are tiny, phenomenally athletic predators – some can leap over 20 times their body length. Australia has some particularly ostentatious species called peacock spiders, which deploy their nifty legwork to attract a mate. Charismatic to the point of cuteness, these 5mm-long arachnids are fondly known as ‘kittens with legs’ by scientists studying their courtship displays. When a male peacock spider sees a potential partner, he takes up position in front of her and raises his third pair of legs. This unfurls a fan-shaped extension to his abdomen, revealing a shimmering pattern created by iridescent scales. Now the male hops side-to-side and bops up and down to show off his velvety technicolour dreamcoat. He also alternately waves his white-tipped legs, as a kind of spider semaphore. It’s a dangerous display, however, since the would-be dad dancer risks becoming the female’s post-coital meal.



TOXIC TOADS

→ PURPLE HARLEQUIN TOAD

Rushing mountain streams in Central and South America are home to the exceptionally flashy harlequin toads, which stand out like a sore thumb in neon purple, green, blue, orange and yellow. These striking patterns, called 'aposematic colouration', are designed to put predators off their dinner. Put simply, it's a 'don't eat me' warning: the toads make a deadly mouthful, as toxins produced by their skin and neck glands rank among the most potent natural poisons yet discovered. Amphibian neurotoxins can easily kill a human, something long known by Amazonian peoples who use them in various (occasionally fatal) rituals, and for hunting. But there is also growing interest from medical science in these secretions, as they could hold the key to creating a new generation of drugs for treating cancer, heart disease and perhaps many other conditions.



FRILLED TO MEET YOU

← FRILLED LIZARD

This dragon-like reptile from the Australian Outback has one of the largest visual displays (compared to body size) in the animal kingdom. A fully-grown frilled lizard can reach one metre from chin to tail-tip. When threatened, it flicks open an orange, Dracula-esque frill up to 30 centimetres across, which normally lies flat around its shoulders. The skin is stretched over several rod-shaped bones connected to the hyoid, or tongue bone, and if the lizard opens its jaws suddenly, these bones splay out, pulling the skin taut and erecting the frill; the wider the gape, the bigger the display. The animal hisses loudly

for good measure, too. But it's all bluff: the frilled lizard is in truth a shy insect-eater that spends most of its time hiding up eucalyptus trees. Should its deterrent fail, the lizard legs it, rearing up on strong hindlimbs in a bipedal sprint like a miniature *Velociraptor*.

Defensive displays that rely on startling or confusing a predator are known as 'deimatic', but male frilled lizards also use their fancy headgear in aggressive encounters with their own kind. In 2013, researchers reported that males with the brightest orange frills were far more likely to dominate paler rivals, winning 90 per cent of fights.

RATTLE AND STRUM

↓ LOWLAND STREAKED TENREC

Evolution runs riot on islands, a fact of life elegantly demonstrated by Madagascar's tenrecs. Having reached the then mammal-free paradise many millennia ago, their single ancient ancestor did as the marsupials of Australia did, and developed into a fabulous array of oddballs reminiscent of shrews, moles, mice, rats and hedgehogs. The streaked tenrec is the family extrovert, scurrying around lowland rainforest with the flexible, earthworm-sniffing snout of a shrew and the defensive chutzpah of a porcupine – those wickedly barbed spines (actually modified hairs) will detach when flicked, impaling a predator. But this tenrec has a hidden talent that elevates it into the wildlife show-off premier league. By vibrating its neck quills, the creature produces high-pitched ultrasound. This 'stridulation' is common among crickets, grasshoppers and beetles, yet no other mammals communicate this way. Madagascar mammal expert Nick Garbutt likens the sound to "dry grass being rubbed together", arguably underselling what is surely one of the weirdest calls of nature.



SEA CHANGE

↓ FLAMBOYANT CUTTLEFISH

Like octopuses, cuttlefish can switch colour, shape and texture at will. These creatures have phenomenally acute vision and may even possess a sense of self, claimed Prof Peter Godfrey-Smith in a recent book about the cephalopods (the class of marine molluscs to which cuttlefish and octopuses belong). Since their skin is packed with chromatophores – elastic, pigment-rich cells wired up to their nervous system – they are able to change colour and pattern rapidly. They can also send repeated waves of intense, pulsating colour over their body, like a light show in a nightclub. Cuttlefish probably first evolved this extreme body-morphing ability as camouflage, then later began using it to startle or confuse predators while making good their escape. Species such as the tropical Indo-Pacific ‘flamboyant cuttlefish’ shown here also deploy spectacular effects during their courtship. It’s one of the most mesmerising and mysterious forms of visual communication in the animal kingdom.

LABOUR OF LOVE

→ FLAME BOWERBIRD

Can animals produce art? Though their craftsmanship is instinctive, the bowerbirds of New Guinea and Australia come pretty close. Adult male bowerbirds devote enormous amounts of time and energy to building complex constructions of sticks and leaves on the rainforest floor, often featuring elaborate symmetry and tricks of perspective. These bowers serve as arenas for luring passing females. When complete, the avian architects decorate their creations with eye-catching trophies gathered from the forest – colourful berries and flowers, glittering beetle wing cases, empty shells or pieces of bleached bone. Yet the task is never-ending: a bower needs hours of daily maintenance, to ensure that any stray twig or leaf is put back in its correct position. Each species of bowerbird includes its own signature design features: the flame bowerbird shown here, for example, adds a fresh coat of mud ‘paint’ every day. Such is the effort involved that the quality of a bower is a fairly good guide to the fitness of the bird that built it. And since females tour numerous bowers, it appears that they are weighing up the males’ relative merits – are they the bird world’s art critics?







STICKING OUT

← *ACHRIOPTERA MAROLOKO*

The world's 3,000 species of stick insect, most of which inhabit tropical forests, have perfected the disappearing act. Some even incorporate imitation leaf buds in their camouflage, or mimic snapped-off twigs and damaged foliage. As is so often the case in nature, the group has a few nonconformists. Two recently discovered giant stick insects from Madagascar have retained the archetypal spindly silhouette, but have traded cryptic colouration for flamboyance. Intriguingly, they are dull-hued when young, only developing their bling at sexual maturity. Scientists speculate that their gaudy adult appearance may help win a mate, or perhaps they absorb and accumulate toxins from leaves while feeding, and are advertising their foul taste to hungry birds. Either way, these stick insects are exhibitionists that play against type. **SF**

by **BEN HOARE** (@benhoare5)
Ben is a science writer and also the features editor of BBC Wildlife Magazine. His latest book, The Wonders Of Nature (£20, DK Children), is out in September.



MASS EXTINCTION... CAN WE STOP IT?

**RESEARCH INTO PAST MASS EXTINCTIONS IS PROVIDING
FRESH INSIGHTS INTO THE ENVIRONMENTAL CHALLENGES
WE FACE TODAY**

by ANDY RIDGWAY

Life has had a bumpy ride on planet Earth. On five different occasions over the past 450 million years, at least three-quarters of all species on land and sea have been wiped out. It's easy to think of these mass extinctions as events in the distant past that bear no relation to what might happen to us in the future – but that couldn't be further from the truth. New research into what killed off the dinosaurs in the 'End-

Cretaceous' extinction – probably the best known of all mass extinctions – is giving us a window into our future by helping us to answer some important questions. As are the other mass extinctions. If life on our planet gets progressively harder, which species alive today will survive and which will perish? Would human intelligence and technology actually improve our chances of survival, or not?

Now is a good time to ask these questions. In May this year, the UN published the most comprehensive report ever written on the fate of all living things on our planet: the Global Biodiversity Assessment. It doesn't make for happy reading. With input from 450 of the world's brightest minds, who synthesised 15,000 scientific papers and government reports, it states that no fewer than 1,000,000 animal and plant species are threatened with extinction – many within decades. It led to headlines that we are now in, or on the brink of, planet Earth's sixth mass extinction. ●

● Google “what killed the dinosaurs?”, or ask most palaeontologists, and you’ll get a fairly clear answer: a 10km-wide asteroid or comet slammed into Earth 66 million years ago, in what is now Mexico. “It hit with the force of over one billion nuclear bombs, releasing a huge amount of energy,” says Dr Steve Brusatte, a palaeontologist at the University of Edinburgh. As well as creating the 100-mile-wide Chicxulub crater in Mexico’s Yucatán Peninsula, it unleashed wildfires, tsunamis, earthquakes and hurricane-force winds. “A lot of animals would have died in the immediate aftermath, particularly if they were within 1,000 miles or so of the impact,” says Brusatte.

The impact choked the atmosphere with dust that blocked out much of the incoming sunlight for several years. “Plants wouldn’t have been able to photosynthesise, and ecosystems would have collapsed,” says Brusatte. Then came 1,000 years of global warming. “The asteroid hit a big carbonate platform [a large body of carbonate rock such as limestone and dolomite] which caused a lot of carbon dioxide to be released, so there was a pulse of global warming,” says Brusatte. “So you had immediate, mid-term and long-term killers. These things combined to kill off the non-avian dinosaurs, along with so many other animal species.” The only dinosaurs that survived were those that eventually evolved into today’s birds. In all, three-quarters of the Earth’s species were eradicated.

NOT SO FAST...

But while the Chicxulub impact is often said to be the sole cause of the dinosaur-toppling mass extinction, there’s growing evidence that this was not the case. In the hundreds of thousands of years running up to the asteroid impact, volcanoes in what

is now India went into overdrive, and Earth’s temperature was yo-yoing, as were the sea levels. This tangled web of factors has led to disagreements about the chain of events that caused the dinosaur extinction, and what was the main culprit.

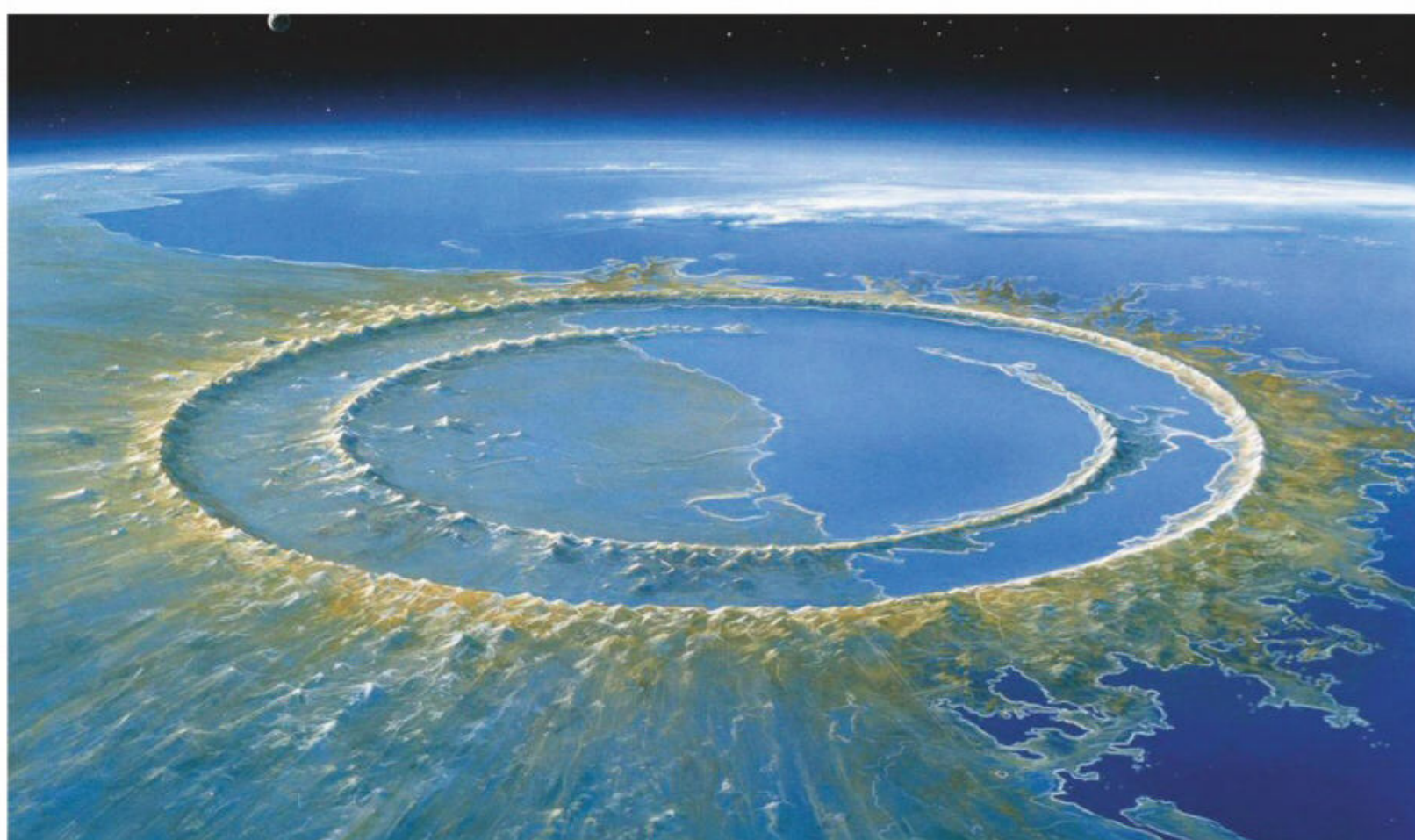
Proponents of the ‘impact hypothesis’, as it is known, suggest it was the asteroid impact that supercharged the volcanic eruptions in the Deccan Traps in west-central India. Others are not so sure. In March 2019, research published in *Science* dated ash from the volcanic activity in India with unprecedented accuracy.

“We showed that the volcanic eruptions went in pulses, with the major pulse lasting about 20,000 years and ending with the mass extinction,” says Prof Gerta Keller, a palaeontologist at Princeton University, who was involved in the research. “But there is no evidence of the asteroid impact causing the volcanic pulse.”

According to this and other research by Keller, the volcanoes set themselves off and played a major role in the death of the dinosaurs. It’s a complex web. Even just unpicking the effects of the volcanoes in India is not straightforward. The CO₂ they released would have caused global warming, while conversely the sulphur dioxide involved would have had a cooling effect. To make matters worse, the dinosaur fossil record is patchy, making pinning cause to effect tricky. ●

“THE CHICXULUB IMPACT
CHOKED EARTH’S ATMOSPHERE
WITH DUST THAT BLOCKED OUT
MUCH OF THE INCOMING
SUNLIGHT FOR SEVERAL YEARS”





ABOVE New research suggests the demise of the dinosaurs may not have been caused by an asteroid impact alone

LEFT The Chicxulub impact caused worldwide disruption to Earth's ecosystems – but they may already have been in a state of disarray



ABOVE Climate change triggered by volcanic eruptions may have helped bring out the dinosaurs' downfall

BELOW Princeton University palaeontologist Prof Gerta Keller has been studying the impact of volcanic eruptions

● But what the last 20 years of research into the End-Cretaceous extinction does show is that several environmental factors conspired to wipe out the non-avian dinosaurs. Not only that, but they died out rapidly. It's now thought that, after being successful for 160 million years (diversifying into over 1,000 species around the world), most of them became fossil fodder in little more than 10,000 years. The situation the dinosaurs were confronted with has

obvious parallels with today. "We have biodiversity loss, habitat loss, climate change and resource extraction," says Dr Lauren Holt, a researcher at the Centre for the Study of Existential Risk (CSER) at the University of Cambridge. "And we also have pollutants – chemicals in the wrong place that are causing further fragility to the system."

WATER WIPEOUT

Another mass extinction – the 'End-Permian' extinction, 252 million years ago – provides further evidence for how rapidly things can go awry. In this catastrophic event, the seas were almost sterilised – 96 per cent of marine species were wiped out. Seventy per cent of land species were annihilated, too. By picking through fossils preserved in rocks in southern China, a team of geologists and palaeontologists from the US and China announced in 2018 that all this death and destruction took place in just 60,000 years, possibly even less – the blink of an eye in geological terms.

"It shows us that any future mass extinction is going to happen really fast," says Dr Jahandar Ramezani, an MIT geologist who was involved in the study. "It's like there's a tipping point, and once you reach that, everything is going to hell." It's thought that, just like the End-Cretaceous extinction that wiped out the dinosaurs, volcanic activity on a monumental scale – this time in Serbia – was partly responsible for the End-Permian event. But other factors had a hand, too, including a reduction in oxygen levels in the deep oceans and changes in atmospheric chemistry. In fact, a cocktail of environmental problems is thought to have been behind all previous mass extinctions (see 'The five mass extinctions', opposite).

Today, potential tipping points in the Earth's climate are the subject of intense research by scientists trying to figure out just how warm things will need to get before a sudden, irreversible change to the climate takes place. The Arctic



GETTY, PETER MURPHY ILLUSTRATION: DAN BRIGHT

is an area of particular concern. If the permafrost melts here, it will release huge volumes of carbon dioxide and methane (both greenhouse gases) into the atmosphere. Meanwhile, if the snow and ice melts, Earth’s surface will be less reflective, so less sunlight will be bounced back into space. If these things happened, climate change would be supercharged. Understanding when these tipping points might occur will go a long way to predicting when the next mass extinction might be.

ADAPT TO SURVIVE

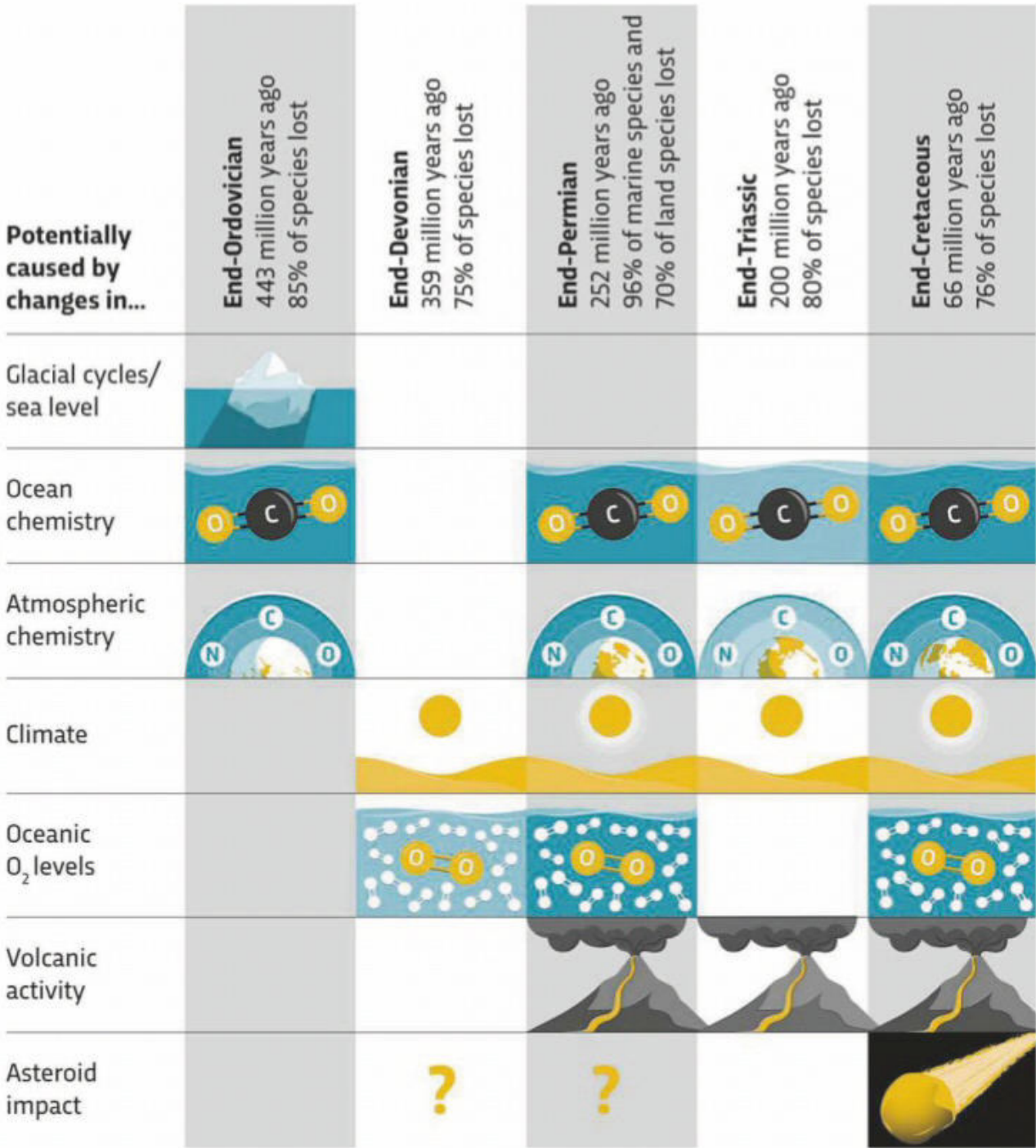
But let’s not forget that, as destructive as the previous mass extinctions were, some life *did* survive. In fact, the extinction of the dinosaurs was good news for the mammals, whose numbers exploded. So what would our chances be in a future mass extinction?

The signs aren’t good. “I think the biggest thing the previous mass extinctions show us is that even the most dominant, successful, widespread and diverse groups can die out,” says Brusatte. “The dinosaurs were on top, and then very quickly they were gone. Now we are in the position that the dinosaurs once were.”

The dinosaurs were specialists, highly adapted to the ecological niches they inhabited, which allowed them to dominate. In mass extinctions, however, it’s the generalists who tend to win out, as they can better adapt to the changing environmental conditions. “It probably means that the subway rats and pigeons

THE FIVE MASS EXTINCTIONS

Scientists have identified five major extinction events in the Earth’s history



“THE DINOSAURS WERE SPECIALISTS, HIGHLY ADAPTED TO THEIR ECOLOGICAL NICHE”

would have a better chance of surviving than the elephants or polar bears,” says Brusatte.

There’s another pattern in what happens to life during mass extinctions: animals tend to get smaller. In what is known as species dwarfing, or the ‘Lilliput effect’, fossil records show that the average size of everything from molluscs to microbes and mammals tends to shrink. Exactly why this happens is unclear, though one possibility is that smaller individuals grow and reproduce faster, and the shorter times between each new generation means they can adapt more quickly to the harsher surroundings.

So in a future mass extinction, it’s probably the smaller generalists that will come out on top. But there’s a good chance that we humans will also have a say in what lives and dies, by pooling more effort and resources into saving certain species. “One of the things that will play a huge role in species’ survival chances is the extent to which

• they're seen as important to human wellbeing," says Dr Simon Beard, who is also a researcher at Cambridge's CSER. "So we're quite likely to see animals and plants such as sugarcane, cows and bananas continuing to dominate the global biosphere."

THE HUMAN FACTOR

While there are parallels between previous mass extinctions and what is currently happening, there's no escaping one key difference – these environmental changes have been brought about by human activity. That does mean, however, that there's something we can do about it. For all its bad news, the UN's Global Biodiversity Assessment says that it's not too late to make a difference.

One thing previous mass extinctions tell us is that we should avoid just focusing on the atmospheric aspect of climate change, says Beard. "Mass extinctions have always

BELOW Here, a huge dip in the ground can be seen where the Arctic permafrost in Herschel Island, Canada, has melted



been largely marine phenomena, since the majority of Earth's biodiversity exists in the oceans. The most destructive changes we currently face may thus be the phenomena of declining levels of oxygen and increasing acidification of the Earth's oceans. These are being driven by increases both in global temperature and atmospheric CO₂."

Then comes the awkward question of whether *Homo sapiens* would ultimately survive. Previous mass extinctions suggest that our survival depends on the answer to a key question – are we specialists or generalists? That's not a straightforward question to answer.

We have become a successful species through immense individual specialisation – by becoming skilled at doing specific things, such as developing technology that allows us to fix the human body, or to grow food in hostile

ARE THE ALIENS ALREADY EXTINCT?

MASS EXTINCTION MIGHT EXPLAIN WHY WE HAVEN'T FOUND ALIEN LIFE

The Universe is unfathomably large and 14 billion years old, which gives plenty of time and space for life to develop on other planets. So why haven't we found it? One possible explanation is that life has the habit of driving itself into extinction.

A look at Earth's history provides some evidence for this. Take the 'Great Oxidation Event' 2.3 billion years ago, when oxygen levels in the atmosphere increased rapidly. "When photosynthesis was first developed by cyanobacteria, the oxygen they released as a waste product was deeply poisonous to other living things," says astrobiologist Prof Lewis Dartnell. "So anything that couldn't adapt or find refuge was wiped out."

Palaeontologist Prof Peter Ward at the University of Washington named the idea that life is self-destructive the 'Medea hypothesis'. He points to the Great Oxidation Event and to other evidence, such as instances where bacteria have produced high levels of toxic hydrogen sulphide, killing off other life. But there's a counter theory, the Gaia hypothesis, in which organisms interact with their environment to create a self-regulating system and maintain the conditions for life.

"Even in the case of the Great Oxidation Event, it was bad for cells that needed oxygen-free environments," says Dartnell. "but an oxygen-rich atmosphere was a prerequisite for all complex life."

Ultimately, we may never know if mass extinctions have occurred elsewhere in the Universe – at least, not until we can make contact with aliens and ask them.





ABOVE It's been suggested that coral reefs could be gene-edited to make them more resilient

environments. "If we evaluate each individual's chances of survival, we really look like toast," says Beard. Collectively, however, we are generalists. "We can survive in space, in Antarctica, in deserts and underwater," says Beard. "All we need is technology." So that's the paradox we will face if environmental conditions really turn nasty.

"Humanity is amazingly adaptable and creative," says Beard. "It's about having the curiosity to solve these problems. If we can do that, there's a good chance of us making it through. But if we can't, then there is a real chance of a total systems collapse. In that case, each of us is on our own. We can't survive that way – it's simply impossible."

Our creativity needs to be applied carefully, though, says Lauren Holt. Take genetic engineering – techniques such as CRISPR gene editing have been suggested as a way to do everything from making coral more resistant to rising sea temperatures, to creating plants that suck more CO₂ out of the

atmosphere. "I don't think people fully understand the long-term implications of things like CRISPR technology on the stability of genomes," says Holt. When an organism's genome is unstable, it's more likely to mutate, causing disease. "If we send organisms out into the world that have augmented ecology, we don't know if that's stable."

As well as the safety of technological fixes for extinction, there are some wider questions to address, too. "Being an adaptable generalist rather than a vulnerable specialist is often referred to as 'resilience', but it's important to accept that resilience is costly," says Beard. "To be adaptable and resilient, we need to develop traits such as redundancy, so we have a backup system in place; preparedness, allocating resources to deal with the most unlikely of potential threats; and flexibility, not being too attached to how things currently are." The trouble is that businesses and governments are striving for efficiency rather than these other traits, says Beard.

So if we can take anything from previous mass extinctions, it's that unity, cooperation and developing a little resilience will make us less like the dinosaurs and give us the best chance of fighting off mass extinction number six. **SF**

by **ANDY RIDGWAY**

Andy is a science writer based in Bristol.

**"HUMANITY IS AMAZINGLY
ADAPTABLE AND CREATIVE. IT'S
ABOUT HAVING THE CURIOSITY TO
SOLVE THESE PROBLEMS"**

ELECTRIC MEDICINE

Researchers in Australia have developed an implantable thread – a sutrode – that could cure disease by stimulating nerve fibres. GORDON WALLACE tells JASON GOODYER its potential for treating epilepsy and schizophrenia, and for producing prosthetics

WHAT ARE 'ELECTROCEUTICALS'?

The name's derived as an alternative to 'pharmaceuticals'. So, 'electroceuticals' is the use of electrical stimulation to treat specific diseases by targeting particular nerves, guiding particular organs. The challenge to date has been to find tools that can communicate with our nervous system with enough resolution or accuracy to target specific nerves.

YOU ARE MAKING 'SUTRODES'. WHAT ARE THEY MADE FROM?

They're threads made of graphene. This wonder material keeps turning up in all sorts of areas. Graphene's just a single sheet of carbon that was discovered not many years ago, for which the Nobel Prize was attributed. There has been an explosion of interest in the material, and the very simple and elegant chemistries that allow us to take a lump of graphite – the kind that you'd find in a lead pencil – and exfoliate or explode it into single sheets of graphene. We do that in such a way that we can control the size of the sheets and also control the amount of oxygen that is on the sheets. That gives us this combination of electrical

properties and processability – the ability to make the fibres. A cocktail of clever chemistries that delivers both of those properties has enabled us to make this particular advance.

HOW DOES IT WORK?

By working with our collaborator Prof Mario Romero-Ortega at the University of Texas, Dallas, we have demonstrated that

Prof Gordon Wallace

Materials scientist Gordon (pictured right) is the director of ARC Centre of Excellence for Electromaterials Science at the University of Wollongong, New South Wales, Australia. He is developing the 'sutrode', a medical device that combines the electrical properties of an electrode with the mechanical properties of a suture.



"WE HAVE DEMONSTRATED THAT WE CAN TIE THESE ELECTRODES AROUND SMALL NERVE BUNDLES"



► we can actually tie these electrodes around small nerve bundles going into organs – the spleen in this case. That’s why we call it the sutrode, because it has the basic mechanical properties of a suture, and yet all of the properties of an electrode. Importantly, it’s an electrode that’s compatible with a living, pulsating system.

WHAT RESULTS HAVE YOU HAD?

Mario and I have both been interested in the field of electroceuticals for some time. In particular, whether the electrical stimulation of the nerves going under the spleen can regulate the immune response. Now, with these new tools, he’s shown that we can definitely record signals from the nerves going into the spleen and that there are different levels of communication through each of those different nerves. The studies are looking at whether you really can regulate the immune response through electrical stimulation of those different nerve types. Before this, you would have to track back to bigger nerve bundles to use conventional electrodes and so you didn’t have that specificity of communication – whether that’s for recording or stimulation – that we have now.

WHAT SORT OF CONDITIONS OR DISEASES COULD THIS HELP TREAT?

At the moment, our studies are focused on the use for nerve and muscle regeneration. In the regeneration studies, and in the electroceutical area, the focus with Mario is on further studies into how we can regulate the behaviour of the spleen through electrical stimulation. And as I say, that regulates the immune response.

But we envisage that as others become aware of what the sutrodes can do, they will establish, or try to establish, collaborations with partners around the world to target other specific diseases using their biological or medical insights into those diseases and our ability to produce the devices and structures.

SO IT TREATS A DISEASE BY DOING WHAT A HEALTHY, FUNCTIONING NERVOUS SYSTEM WOULD BE DOING?

Yes, so in terms of the electroceuticals, it’s trying to restore the natural behaviour of the neurosystem [nervous system] in controlling organs.

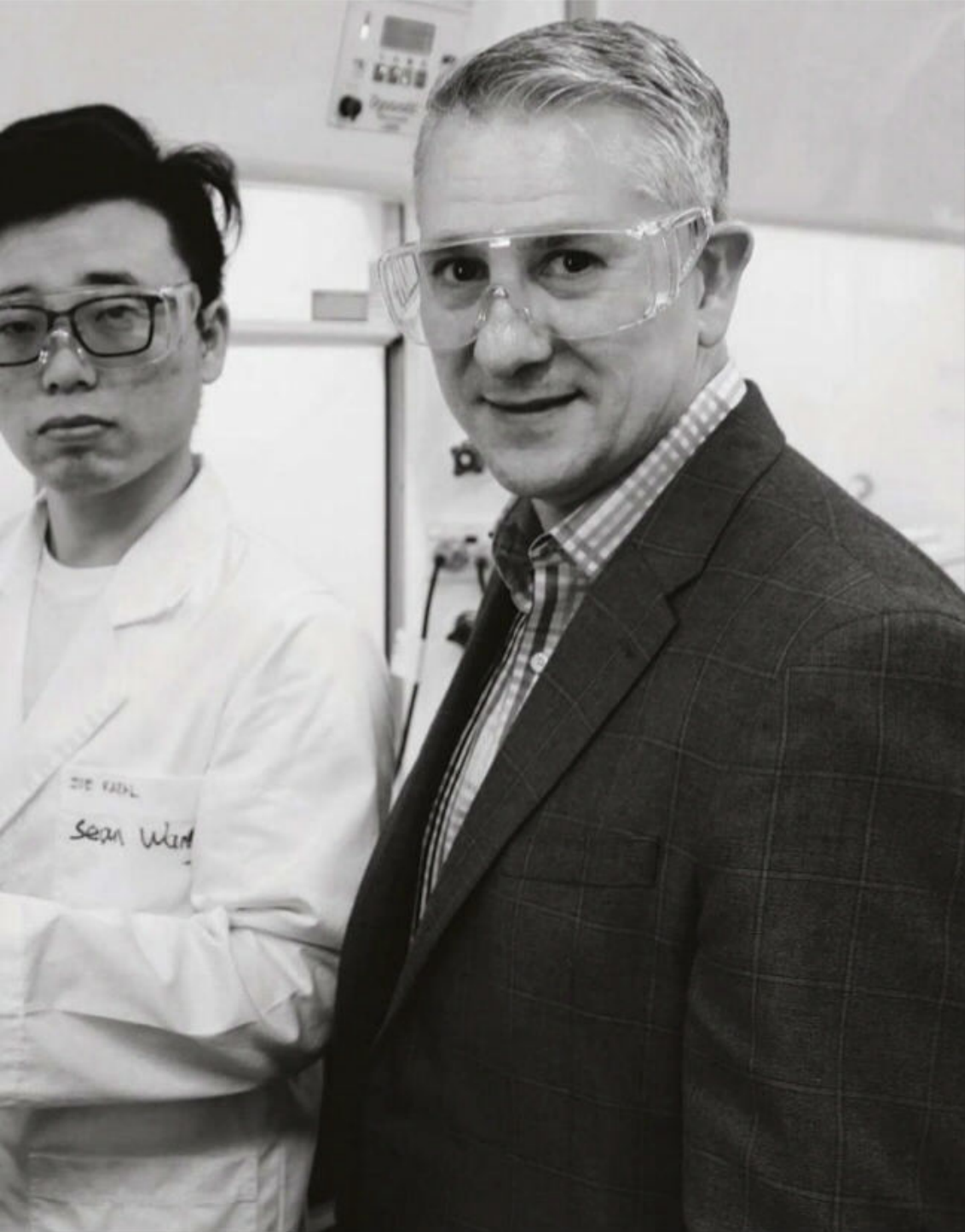
In terms of nerve or muscle regeneration, the sutrode promotes the healing process by providing a conduit that facilitates the repair or regrowth of nerve connections, or the alignment and restoration of muscles.

“THE SUTRODE PROMOTES THE HEALING PROCESS BY PROVIDING A CONDUIT THAT FACILITATES THE REPAIR OR REGROWTH OF NERVE CONNECTIONS”

WHAT IS GOING ON IN THIS NERVE BUNDLE WHEN IT GETS STIMULATED BY THE SUTRODE?

We’re just learning about that. We’ve been able to show that we can record, with incredible sensitivity, the electrical impulses that are generated by this nerve bundle. And then we’re figuring out what those different electrical impulses do to the organ, and what biological responses can be regulated. By superimposing electrical impulses from our sutrode over this system, we hope we’ll be able to influence how it works.





Prof Gordon Wallace (left) and Prof Mario Romero-Ortega (right)

WHAT ADVANTAGES WOULD THIS SORT OF TREATMENT HAVE OVER REGULAR MEDICINES, LIKE INJECTIONS AND TABLETS?

I think the ability to target the disease more specifically. The ability to deliver the stimulation when it's needed to treat those diseases, and in some cases, potentially, a much more effective way of actually treating particular diseases.

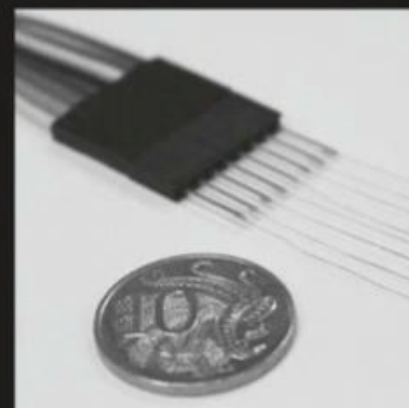
Diseases like epilepsy or schizophrenia are not very well treated by normal pharmaceutical approaches, and treatment often ends up being a cocktail of drugs that are personalised for that individual. It's basically a trial and error process.

WILL THE SUTRODES BE PUT INTO THE AFFECTED AREA AND THEN LEFT THERE? OR ARE THEY FOR SHORT-TERM USE?

Look, in terms of electroceuticals, the real answer to that is we don't know. Can you actually reverse the disease by electrical stimulation for a certain period, and then not need to stimulate any further? These are all studies that need to be done.

DISCOVER MORE

ON THE PODCAST
You can listen to our full interview with Gary in an upcoming episode of the Science Focus podcast sciencefocus.com/science-focus-podcast



The threads seen here are the sutrodes, wired up to an electric circuit

In terms of other applications of these sutrodes, for example, in nerve repair, nerve regeneration or muscle regeneration, because of the mechanical properties of the fibre, we envisage it will be fine just to leave them in there to do the repair and then to leave them as part of the naturally restored system.

IN TERMS OF COST, HOW DO THESE COMPARE TO TRADITIONAL MEDICINES?

The cost of the actual materials is incredibly low. We're talking about graphite out of a mine, and simple chemistries and fabrication methods to make them. So, there's no huge cost involved in that. And in terms of the hardware to drive them, the cost is low as well. So, materials and fabrication costs are quite low compared to if you were developing a whole manufacturing process for a new pharmaceutical, for example.

WHAT WILL THE FUTURE OF THIS RESEARCH LOOK LIKE?

The focus in the near future will be in nerve and muscle regeneration. We will, of course, pursue different areas of electroceuticals with collaborators as we establish them. One other area that will use these materials, given their effective ability to communicate with nerves and muscles, is as an interface for neurally driven prosthetics, like a prosthetic hand.

WHAT DO YOU MEAN BY 'NEURALLY DRIVEN'?

Basically, the nervous system will communicate directly and send electronic signals to a prosthetic hand to drive it via a sutrode. And by incorporating sensing technologies into the hand, it will provide sensation back to the user.

SO, IF I NEED A PROSTHETIC HAND I'D BE ABLE TO CONTROL IT IN THE SAME WAY THAT I CONTROL MY OWN HAND?

Yes. Exactly. Now, that requires a high-fidelity neural interface to the prosthetic, and we believe that's exactly what we've got in the sutrode, and that's something we'll be pursuing. **SF**

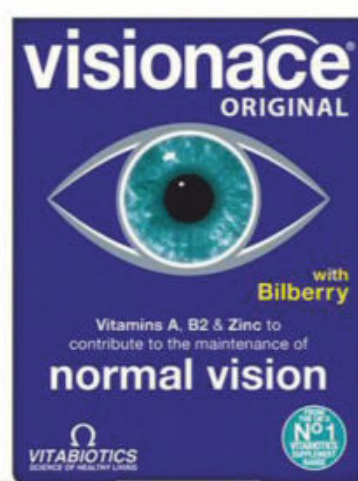
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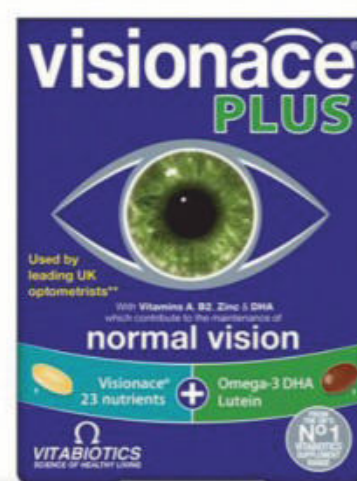
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COMMENT

CRACKING THE KETO DIET

Could a low-carb diet help boost brain function?

Diets come and go, but one that seems to have more sticking power than most is the Keto diet. This is a very low carbohydrate diet, which involves higher consumption of fats and proteins to compensate.

In many ways, the Keto diet is simply a reinvention of the Atkins diet, which in turn was a reinvention of the Banting diet. This diet was named after William Banting, an obese Victorian undertaker who in 1863 published his famous *Letter On Corpulence*, outlining the benefits of cutting down on carbs. The Keto diet has its critics, but there is evidence that, at least in the short term, it can help with weight loss and may be beneficial in treating type 2 diabetes.

When you drastically cut your carbs, your body switches to using fat as a fuel source, in the course of which it generates ketones. The brain can use these as a source of fuel, along with glucose. In some way, the brain seems to benefit from this switch. We have known for a long time that a low carb diet can be effective in the treatment of epilepsy.

Fans of the Keto diet will also be delighted by the results of a new study published in the *Journal Of Alzheimer's Disease* showing that it may be beneficial for people who are showing early signs of cognitive decline. These claims are based on a small pilot study of 14 older adults with mild cognitive problems,

“Improvements in memory coincided with peaks in the volunteers’ ketone levels”

nine of whom researchers from Johns Hopkins University School of Medicine put on a modified Atkins diet (MAD). The other five people went on a standard, ‘healthy’ diet.

The volunteers on the MAD diet were asked to stick to less than 20g of carbs a day, with no restriction on calories. A typical US diet contains more like 250g of carbs a day. To check they were sticking to the diet, the volunteers had regular checks of their urine using keto sticks. These measure unused ketones, which are excreted in your urine.

So how did the MAD dieters get on? Well, both groups were asked to complete numerous cognitive and memory tests before starting their diets, at six weeks and then again at 12 weeks. The researchers found that there were significant improvements on memory scores, but only in the MAD group. The improvements in memory coincided with peaks in the volunteers’ ketone levels, as measured by their urine.

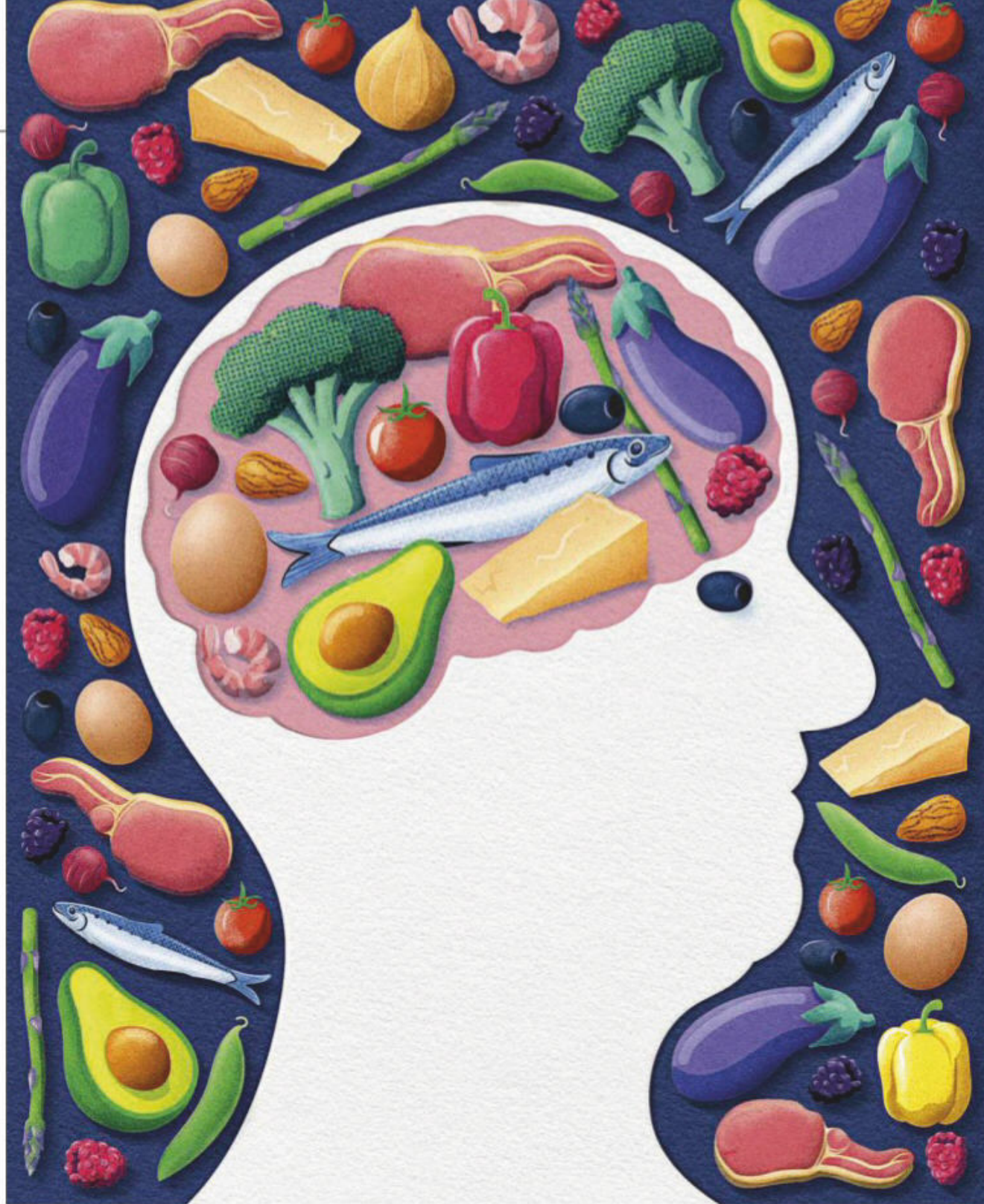
Dr Jason Brent, who is professor of psychiatry at Johns Hopkins University School of Medicine, and the lead researcher in the study, thinks that the results are promising. He wants to see if a milder version of this approach, supplemented with ketone drinks, would be just as effective.

While I’m not yet ready to give up eating bread entirely, I await the results of further studies with great interest. **SF**



MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *The Fast 800* (£8.99, Short Books).



THE ART OF GOOD STORYTELLING

With a potential audience of millions at our fingertips, it's important not to be flippant with the facts

There's a story I have been trying to write since 1994. And yet, I find myself unable to tell it. I think it's because it's not my story. It's because I feel a huge weight of responsibility to tell it right.

The elevator pitch is this: my grandmother and her octogenarian friends meet every six weeks at someone's house in Orange County, California, to celebrate one of their birthdays. They drink wine, exchange cards with dirty jokes on them and boast about their grandchildren. But in the 60 years they've known one another, they've never talked about the one thing that unites them: as teenagers, they were all spies for the Allies in their native Poland during WWII.

Compelling, right? I bet a few of you would love to read it. So would I. Problem is, I'm the one repackaging it, rearranging it, filling in the blanks and creating a compelling narrative. Their story is intended for a general audience, and so it doesn't have to be accurate; my job is to tell a great yarn.

We are all getting good at this. More than any other point in history, we are publishing stories about other people. Generally, they're not as formal as

✕
“As teenagers, my grandmother and her friends were all spies in Poland during WWII”
 —

the one I'm trying to compel out of my fingers – most are observations about life in 280 characters, or photo essays of our kids that started before their bodies were fully formed. We create side characters in our Twitter feeds, and guest stars on our Facebook profiles. We have taken away people's agency to tell their own stories, and represent their own lives.

This is mostly as it always has been. Cognitively, it's impossible to stay sane while empathising with everyone around us. As storytellers, the only thing that'll stop us from filling in the blanks about people's lives is the invention of a mind-reading machine. And given the amount of nonsense most of us think

about, we'll probably regret it. But here's the difference: whereas in the past our tales about others might reach a small circle of people, now with printing presses in our pockets we could reach an unimaginably huge audience. That could spell bad news for the people we've caricatured. Your neighbour might have been wearing his Incredible Hulk pyjamas when you popped round at 8pm because his more sophisticated pair were in the wash. Still, he's now the goofy, geeky neighbour. Maybe the fabricated details of the story you live tweeted about the people sitting in front of you on the aeroplane 'falling in love' ended up getting one of them into serious trouble with an actual partner on the ground. Who knows? We don't.

It's our responsibility to use our innate storytelling ability wisely and sensitively. Sure, it might paralyse the spinning of a good yarn, but I'd rather be careful about the details than end up creating irrevocable rifts. We don't just have to be careful about what we say about ourselves any more, but what we say about one another too. **SF**



ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *Digital Human*.



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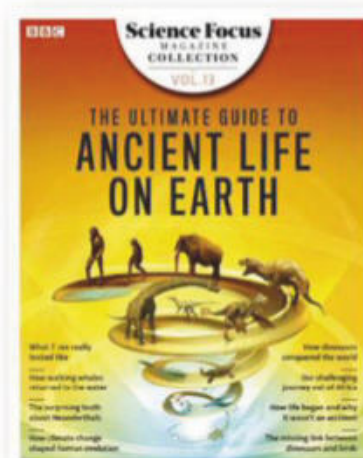
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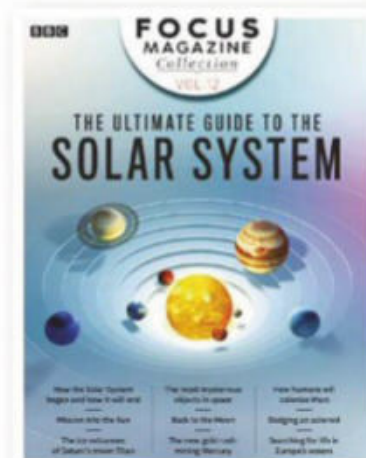
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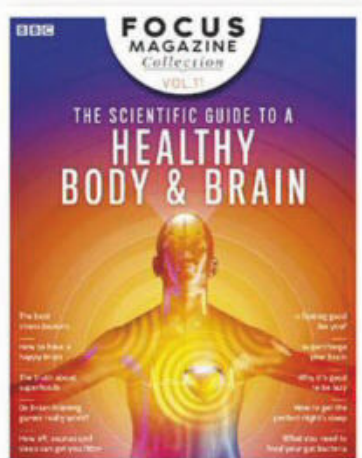
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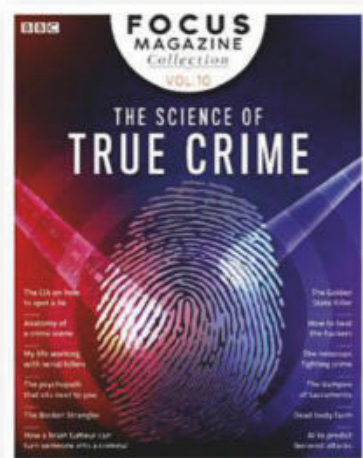
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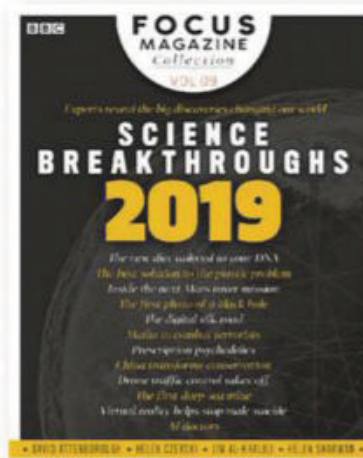
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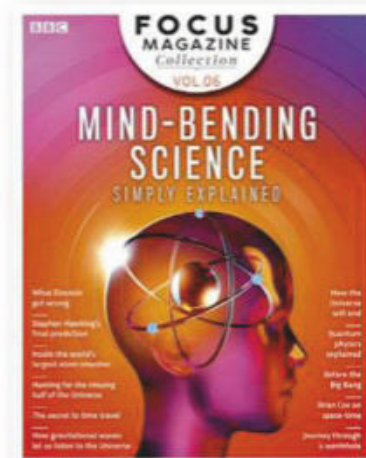
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BURN, IN THE NAME

USDA FOREST SERVICE



OF SCIENCE!

Experts believe that with drier, hotter weather becoming the norm, even more wildfires could rage in the future. That's why scientists are monitoring intentionally ignited fires, and using computer models, laser scanning and drones to predict the behaviour of the flames and help prevent widespread devastation...

by HAYLEY BENNETT

At past midnight on a Thursday night in June, researchers in Utah are still sending excited emails, updating each other on the day's action. The team has just finished following a huge fire that has ripped through a remote area of the Fishlake National Forest in the south of the state. And they're still buzzing.

This was no wildfire. It was intentionally set. Early in the afternoon, ignition helicopters were sent in to start the burn. Utah University atmospheric scientist, Adam Kochanski, watched the flames unfold. "There were two helicopters with so-called heli-torches – kind of like flame-throwers – just suspended beneath," he recalls. "They were flying back and forth, and on top of that there were some ground crews with handheld torches and they also started fires on the ground." It took a while to get going, but once it did, the fire burned fast and heavy for a couple of hours, consuming eight kilometres of national forest before petering out into the night.

BURNING AMBITION

For Kochanski, this was a unique opportunity to test something that he'd been working on. A few hours before the burn, he'd been sitting at his computer, using a model he was developing to try to predict how the fire would pan out. "It was the very first time we were able to initialise those forecasts in the field, just in the middle of nowhere – everything on the fly and on your laptop," he says. Meanwhile, other researchers were using drones fitted with infrared cameras, laser scanning techniques and instruments on towers dotted around the forest to track every aspect of the fire, the smoke that came off it and local conditions such as wind speed. It was one big experiment.

But not *just* one big experiment. Perhaps you're wondering why it's okay to start a fire in a national forest, even if it is in the name of science. Well, that's not quite all that happened. As Nancy French, a Michigan Tech University scientist who helped coordinate the team, explains, the fire was happening anyway. It was what's known in forestry as a 'prescribed fire' or 'controlled burn', one that's set to achieve some ecological aim. In this case, it's for habitat restoration. The fire was carefully planned and managed to make way for young aspen trees, which are grazed by elk. "This area was overmature spruce and now they will be really encouraging it to turn into habitat that's preferable for the elk," says French. "So that's the reason for the fire and what we were doing as scientists was piggybacking on top of that."

In fact, the scientists didn't have much say in



how or when the fire happened. With prescribed fires, it's the 'burn boss' – someone experienced in setting these type of fires – who is in charge of decision-making. The number one goal is safety: if there is any sign of drought or dangerous burning conditions, the fire gets cancelled. The burn boss gives the thumbs-up only when conditions are first, safe, and second, likely to achieve the ecological aims. In fact, in June's Fishlake fire, the decision to burn came after a period of deep snow, when the 'fuels' – what fire scientists call trees, along with other stuff that burns – were dry enough.

When it was clear the burn was going ahead, the scientists came, laden with instruments, to study every aspect of it. An advance party had already looked at the 'fuels' before the fire and would return again afterwards to see what burned. Then there were researchers involved in studying how the fire itself behaved, monitoring the smoke plume and the chemistry of the smoke. "It's a pretty big operation," says French. As well as scientists, forestry staff and safety coordinators, there was even someone with the dedicated task of de-conflicting – basically, ensuring that the drones weren't up at the same time as the helicopters. So what did the scientists get out of this giant blaze? According to French, it will take six months to a



1. Ignition torches were used to create smaller fires in the days before the main burn

2. Plucky drones soar into the choking clouds from the forest fire to obtain smoke samples, which can then be chemically analysed

3. A helicopter soars over Manning Creek, to ignite one of the fires



“FOR WILDLAND FIRES, THERE’S SO MUCH ENERGY THAT THE FIRE CAN GENERATE ITS OWN WEATHER”

year to really unravel the results, but the hope is that they will have a rich set of experimental data with which to furnish a new generation of fire and smoke behaviour models. These cutting-edge models – dubbed ‘coupled fire-atmosphere models’ – will combine information about the fire and the local weather conditions to produce more accurate forest fire forecasting. As Kochanski explains, the current models don’t account for how the fire itself affects the weather. “For wildland fires, there’s so much energy that the fire can generate its own weather,” he says. “So it modifies local winds, it modifies temperature, it can generate huge clouds. It can generate precipitation, just because of the moisture coming from the fire.”

FIRE DISTINGUISHER

A fortnight after the big burn, Kochanski shares the forecast he created for the fire at Fishlake over Skype. It’s a little rough: a two-dimensional rendering of the fire from above, superimposed over a map of the forest, with little arrows pointing in the direction of the wind. The fire is in grey and there’s a wandering puddle of blue that’s supposed to represent the smoke plume. As Kochanski runs the simulation, the plume grows and spreads, then retreats, before disappearing. Here, the model predicted that rain would set in and that’s exactly what happened in reality. After two hours of burning, the rains arrived and the fire died out.

On the face of things, it seemed like the model worked well. The team was even able to decide where they should view the fire from without getting smoked out, based on their model’s predictions about where the smoke was going to go. But according to Kochanski, the hard work hasn’t started yet. All the data collected on-site has to be incorporated into the model to see whether it is able to capture the real detail of the burn – the height of the smoke plume, the fire intensity and so on. The new data will help the team make some refinements to get it working even better, which means it should produce a more accurate simulation but also, eventually, better forecasting for future fires.

“It’s really updating the knowledge that’s used to make the models operate better,” says French. Some of the sensing technology available now is far more sophisticated, she explains, than what was used to inform older models. And there are plans to collect yet more data this autumn using one of NASA’s sub-orbital ER-2 planes, a so-called flying laboratory stacked with sensors, as well as a DC-8 passenger plane that will fly through the smoke plume collecting data about its chemistry. It all sounds like first-class science, but the project has struggled due to budget cuts. From French’s

➤ perspective, they now have good quality data, but making use of it could be a thankless task if they don't find some extra funding. Even Kochanski admits that working up the simulations from Fishlake might be a hobby project until he can figure out how to pay for it.

Despite the funding cuts, many of the scientists on site at the Fishlake fire paid out of their own pockets

“THE IMPROVED MODELS COULD MEAN BETTER PREDICTIONS ABOUT WHERE THE SMOKE IS LIKELY TO GO AND WHEN”

to be there, which says a lot about how valuable they believe the work to be. It's partly about the importance of improved models for predicting the behaviour of wildfires. In the last decade, wildfires have consumed between around 16,000 and 40,000 square kilometres of US land each year, according to statistics from the National Interagency Fire Center, and caused financial losses totalling \$5bn (£4bn). Last year, California suffered the largest and deadliest wildfires in its history, with one fire in the north of the state killing 85 people. Globally, the stats are just as frightening.

Kochanski says their experiment represents the closest it's possible to get to a real wildfire while having all the necessary fire and weather monitoring equipment in place. “You can imagine that if a fire is roaring somewhere in California, there is no way to put enough sensors in. There isn't enough time, there are safety concerns and no one is even going to be allowed to get close to the fire perimeter. So for wildland fire, it's impossible.”

AHEAD OF THE FLAME

While a wildfire might be 100 kilometres away from the nearest weather station, the burn area at Fishlake had several stations of its own. Based on this more detailed data, it should be possible to build models and tools that can help the people who have to make decisions about how to fight wildfires. It could help firefighters to know how the fire is likely to behave, so they can be one step ahead.

The improved models could also mean better predictions about where the smoke is likely to go and when. Kochanski suggests early warning

BURNING ISSUE

Wildfires cause widespread devastation all around the world

13,131

Spain's average number of annual forest fires between 2006-2015. More than half are thought to be started by arsonists.

9,500

Distance travelled, in kilometres, by smoke from Russian forest fires in July 2018. The smoke reached Greenland.

14,000

The maximum number of firefighters deployed simultaneously to fight forest fires during peak fire season in California in 2018.



The researchers gained data about wildfires by monitoring the behaviour of the smoke at Fishlake National Forest

systems could give communities more time to react, ensuring that vulnerable groups stay out of the smoke. Schools, for example, could be warned to keep children inside at break times. Currently, it's more a case of telling people to stay at home as the smoke is already drifting over their house, when it's too late because they've already made plans. "But if you can provide this information earlier," Kochanski says, "If you can tell people, 'hey, between 4pm and 5pm tomorrow, you will be smoked out, so just plan accordingly', that's a different story."

That's not all though. Improvements to fire modelling could also help forestry workers like those who carried out the prescribed burn at Fishlake. Setting a fire is not normally an exact science. Most of the time, says Kochanski, "they just go with their gut feelings" – albeit based on plenty of experience. They've never had the level of data this new experiment provides. It could change the game entirely, helping them to burn more effectively to meet their ecological objectives. Which, at Fishlake, could work out well for the elk.

Once you appreciate everything that's riding on this experiment, it's not hard to see why the scientists were so eager for it to go ahead – or why they were so pumped when it all went to plan. But that was just the pyrotechnics part. For Kochanski, it's the nature of the data collection that makes this project "absolutely unique". So it's the nitty gritty of the analysis that should prove its worth. This part, it seems, could be more of a slow burn. **SF**

by **HAYLEY BENNETT**

@gingerbreadlady

Hayley is a science writer based in Bristol, UK.

540

Number of people evacuated from their homes in 2018's Treuenbrietzen forest fire in Germany.

\$26m

A palm oil company's fine for burning 10 square km of Tripa Forest, where tigers, elephants, rhinos and orangutans still coexist.

41,000

The area, in square km, of US forest burned by fire in 2015. This is the greatest annual loss to fire in the US since records began.

39m

The amount of methane, in tonnes, released by forest fires each year. Methane is a more potent greenhouse gas than carbon dioxide.

25

The speed, in km/h, of spreading bushfire during the State Mine Fire, Australia, in 2013. It burned 4.5 million square km.



What would alien life actually look like?

As we discover ever more planets orbiting other stars, and plan missions to potentially habitable moons of Saturn and Jupiter, will we find life – and if we do, will we even recognise it?

by MIĆO TATALOVIĆ

Our Universe could turn out to be a pretty wild place. Recent astronomical discoveries suggest that billions of Earth-like planets are dotted throughout our Galaxy, which is just one of billions of galaxies in the Universe. “Our best estimates are that one in four stars have a planet that is the same size and the same temperature as the Earth. That’s very high,” says David Charbonneau, professor of astronomy at Harvard University, US.

And many scientists now think there is life on at least some – if not many – of those planets and their moons. One of them is Dr Chris McKay, a planetary scientist at NASA’s Ames Research Center, who says that we can assume that life is widespread based on “two simple facts”.

First, the chemical elements of life, such as nitrogen, hydrogen and oxygen, are widespread in the Universe, as are the two key compounds of life on Earth: liquid water and organic carbon. Second, we know that life was present

on Earth very early in its history – soon after the planet was formed – which suggests that once the conditions are right, life springs up easily and quickly.

“If the origin of life is widespread, then complex life will be widespread,” says McKay. That means we might expect to find more than just single-celled microbes out there. “The best way to find out is to go look.”

Some scientists and entrepreneurs are already thinking about how to get to distant stars quickly. Yuri Milner, a Russian tech entrepreneur, came up with

the Breakthrough Starshot project, which proposes that tiny chips could be attached to craft propelled through space by an intense Earth-

based laser. If it works, this would cut the travel time to the closest star system, Alpha Centauri, from 100,000 to just 20 years. The first tests of early designs took place this May.

In the meantime, two NASA missions are set to shine light on the atmospheres of planets that orbit other stars (exoplanets), pinpointing those that could harbour life. The TESS mission started collecting data this year, and the James Webb Space Telescope is expected to launch in 2021. “We know virtually nothing about the actual conditions on those planets,” says Charbonneau. These two missions will change that.

VISIONS OF OTHER WORLDS

Some of science’s brightest minds have already brainstormed what we might expect to find, and their conclusions formed the basis of two cult documentaries, *Natural History Of An Alien* and *Alien Planet*, which first aired in 1998 and 2005 respectively. The two films inspired many people ●

“IF THE ORIGIN OF LIFE IS WIDESPREAD, THEN COMPLEX LIFE WILL BE WIDESPREAD”



to think about how other life may be similar and different on other planets. Indeed, some scientists are now trying to lay down the science of not only how life-as-we-know-it would be different in space, but also of what exotic life that was made of other chemicals might be like.

These shows parted with the common fictional view of sentient green aliens, and they applied rigorous thinking by evolutionary biologists, biomechanics experts and astrobiologists to design plausible living worlds within the restrictions of alien geology and planetary science. Many scientists think the unlikely-sounding creatures dreamed up for these shows two decades ago are still as good a guess as we have for what alien life will look and behave like. Though, with myriad of discoveries since, we also now have new insights that paint an even wilder picture.

“On any planet in the Universe the laws of physics and chemistry will still be the same as here,” says Prof Peter Ward, a palaeontologist at the University of Washington, Seattle. “There’s only a limited number of ways to beat physics.”

Even in outer space, he argues, on an Earth-like planet there would be similar physical constraints leading to the evolution of similar life to what we have on Earth. The premise is that there are only so many ways one can efficiently see, hear,

walk, swim or fly – and that natural selection will largely weed out inefficient body plans, as it has on this planet.

This means we can make educated guesses about what such life would look like, based on our biological understanding of evolution, and our geological and climatic understanding of conditions on other planets. Most of the scientists interviewed for this feature said the educated

**“EVEN ON EARTH, LIFE GIVES
RISE TO RADICALLY DIFFERENT,
SOMETIMES UNIQUE LIFE FORMS
AT DIFFERENT TIMES AND IN
DIFFERENT PLACES”**



ABOVE NASA's Transiting Exoplanet Survey Satellite (TESS) launches onboard a Falcon 9 rocket at Cape Canaveral, April 2018

guesswork in the TV programmes mentioned previously might not be too wide of the mark – if anything, those visions might be too tame, given the potential for the vast amount of life that might have evolved on very different planets.

“The Universe has a way of surprising us,” says Theresa Fisher, an astrobiologist at Arizona State University, US. “My suspicion is that, with a range of environments that we could be looking at, it could feel very alien.”

She says that any life would be expected to follow the broad principles of ecology: it would need to have a way of getting energy, and there would be competition leading to the emergence of predators and prey, for example. But beyond that, it's anyone's guess what life might look like. “There's no reason that it would have to be particularly similar to what we see on Earth.”

STRANGER THINGS

So we can't really say that alien life would look like Earth life. Even on Earth, life gives rise to radically different, sometimes unique life forms at different times and in different places.

When dinosaurs went extinct, what came after them wasn't more of the same. And the flora and fauna of New Zealand, with kiwi birds and practically no land mammals, are very different

from those of the Serengeti, with its elephants and giraffes, or Madagascar with its lemurs.

For unique life forms on Earth, look no further than seahorses, says Dr Lauren Sallan, a palaeontologist at the University of Pennsylvania. The animal shares basic components of other fish but has a unique shape, and reaching that form required a very unlikely evolutionary pathway. “You do get weird things that happen once – both now and in the distant past,” says Sallan.

On an Earth-like alien planet, things could get even weirder. It's possible that we wouldn't even recognise them as life, given that our current efforts focus on finding “life as we know it”, says Casey Brinkman, an astronomer at the University of Hawaii: “There's all sort of possibilities out there for weird stuff.”

Sallan agrees. Any life forms will have to get energy, but the way they would go about it is hard to predict, she says. “They would be filling similar ecological roles, but whether we would recognise them without a lot of study – I doubt it.”

So to start with, astronomers are focusing their search on signatures of life that we know from Earth, such as oxygen. They're also focused on finding Earth-like rocky planets where liquid water could exist. “We have to begin with a search for life as we know it,” says Charbonneau. ►

“There could be life that’s very different than life on the Earth, but we wouldn’t recognise that in our data, because we don’t know and understand that chemistry very well,” he adds.

WHEN GRAVITY MEETS BIOLOGY

There are many different conditions on other planets and moons, beyond chemistry, that could affect how life would evolve there. Take gravity, for example. On a bigger or denser planet, the gravity would be higher, meaning that life would evolve to be shorter, sturdier and perhaps with multiple limbs for structural support. Conversely, on a lighter planet with weaker gravity, life could hop, soar and glide more easily, and would be more likely to evolve a lighter, taller build.

The density and chemical makeup of the atmosphere would affect how easy it is for life to take to the skies: denser air would allow for more life forms treating the sky like an ocean they can ‘swim’ in, while oxygen-rich air would fuel more energetic creatures.

The seasons could be vastly different, too. Many planets have much shorter orbital periods than the Earth’s 365.25 days, speeding up seasonal changes to weeks or days rather than months. Some planets have more elliptical orbits that would make seasons much more



ABOVE Launching in 2021, the James Webb Space Telescope will tell us more about exoplanets, their atmospheres and their potential for hosting life

extreme, with scorching, short summers followed by long, deep-freeze winters.

The type and number of stars a planet orbits, as well as how closely it orbits them, would also affect how much solar energy and radiation it receives, and whether photosynthesis is possible or whether life would have to instead rely on chemosynthesis – using energy derived from reactions involving inorganic chemicals rather than sunlight.

The majority of stars are red dwarfs, says Charbonneau, which are less energetic and more durable than our Sun, so could offer longer time periods for life to evolve. But, early on in their evolution, such stars emit a lot of radiation that could be harmful to life and planets’ atmospheres, or even eliminate them. *Alien Planet* envisaged life around such a star as plant-like creatures that could fold up to protect themselves when there are solar flares, and dinosaur-like animals with a third eye on top of their heads to give them early warning that a burst of radiation is on its way.

Closer to Earth, many scientists hope we’ll find life in space within our lifetime, possibly on the icy moons of Saturn and Jupiter, such as Enceladus and Europa. “I’m willing to bet you a flat white that in the next 20 years we’ll find some life,” says Dr Seth Shostak, senior astronomer at the SETI Institute, US. “It will probably be microbial life squirting out of Enceladus or maybe Europa, or maybe under the sands of Mars: there are all these places in our own Solar System where we could find this stuff.”

**“MANY SCIENTISTS HOPE
WE’LL FIND LIFE IN SPACE
WITHIN OUR LIFETIME,
POSSIBLY ON THE ICY MOONS
OF SATURN AND JUPITER”**

WEIRD WORLDS

Life could possibly exist on any number of different types of planets and moons that have very different properties, which would shape the evolution of life there. Here are just a few of them, together with the challenges and opportunities they would pose for life

YO-YO PLANETS

Unlike Earth's circular orbit, these planets have elongated, elliptic orbits that bring them very close to their sun for brief periods of scorching hot summers, and then take them far away from it for long, freezing winters. There would be two brief growing periods when the planet is approaching and departing the sun, when Earth-like life could blossom, but it would have to be adapted to endure the evaporation of its oceans in the summer and snowball planet periods in wintertime.

TIDALLY-LOCKED PLANETS

Many planets orbiting close to their star get locked by their sun's gravity so they always face the sun with the same side. This means one side of the planet is plunged in constant darkness, while the other always basks in sunshine. This could create a massive, ongoing storm in the centre of the Sun-facing side and freeze over the other side of the planet, leaving a strip in-between with possibly Earth-like conditions. Air and ocean circulation could allow the exchange of heat between the two sides, perhaps fuelling some life on the dark side.

LAYERED OCEANS OF GANYMEDE

Some scientists think Jupiter's moon, Ganymede, has several layers of oceans underneath its frozen surface, each separated by a different type of ice that forms at certain pressures and temperatures. If there is life there, it would most likely have originated in the bottom ocean layer where it meets a rocky base. Eventually, some life might have made its way into the next layer, finding an unexploited new habitat and possibly adapting to different conditions there, and later moving on again to yet another layer. This would essentially create vertical continents, each with its own life forms and ecosystems – but all with a common origin.

ROGUE PLANETS

Some planets get ejected from their orbit around their host stars and become lonely wanderers through the Universe. Cloaked in cold and darkness, they could remain habitable for any life, fuelled by the internal engine of their hot cores, for billions of years – but that life would have to adapt to no sunlight and rely on chemosynthesis, like life deep inside Earth's rocks and oceans. "There is plenty of heat in the

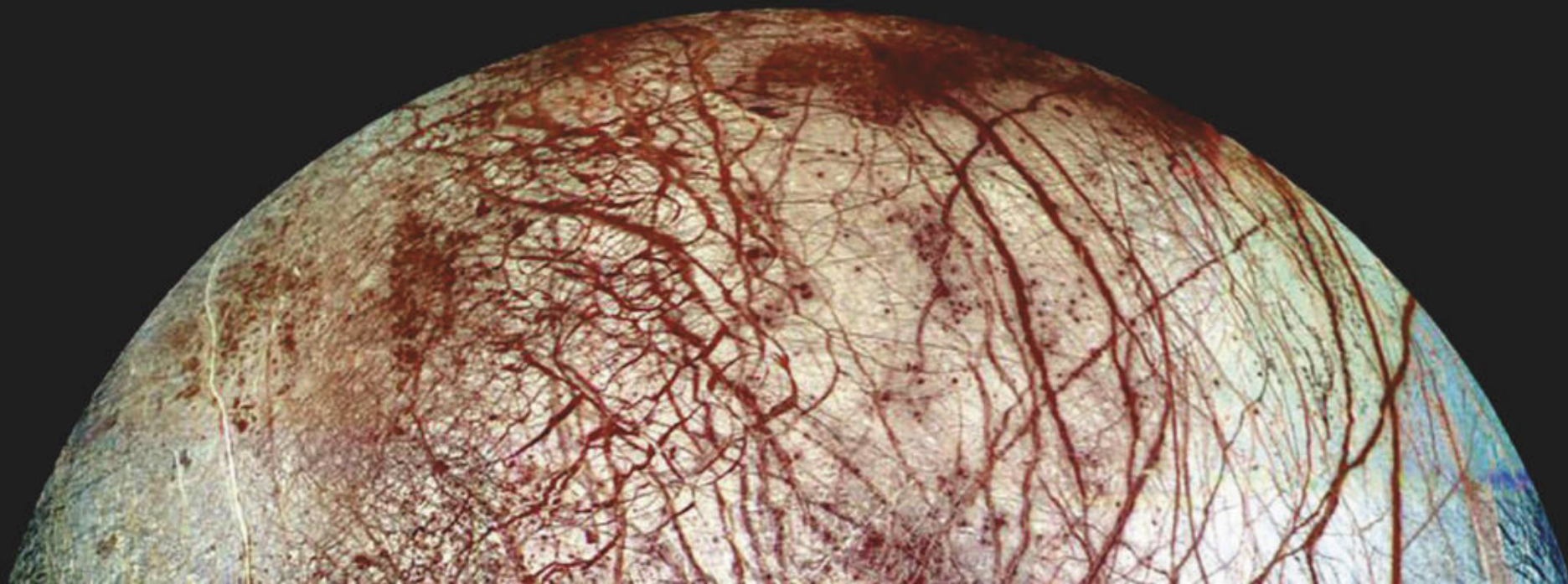
interior of a planet for billions of years; it is longer than the lifetime of host stars," says Dimitar Sasselov, astronomy professor and director of the Harvard Origins of Life Initiative.

DISCO-BAR PLANETS

Around pulsar stars created after the explosion of a star, planets would be devoid of much sunlight and any life would have to rely on chemosynthesis, though its chemistry may be very different as such planets are unlikely to have many organic molecules common on Earth. Such planets would be dry, metallic and bathed in the pulsating light of their star.

LIQUID METHANE WORLDS

Titan, the moon of Saturn, appears very Earth-like with its hills, rivers and lakes filled by rains from its clouds. But it couldn't be more different: temperatures are freezing, turning water rock-hard, and the only liquid present is in fact methane, the major component of natural gas here on Earth. If life exists there, it will most likely be based on different chemistry to Earth life, and probably evolve very slowly because colder temperatures slow down chemical reactions.



WHAT ALIENS MIGHT LOOK LIKE

Scientists have long speculated about what living creatures on other planets and moons might look like, based on what we know about those planets and the principles of evolution and biomechanics. Here are some of the strange organisms they have imagined...

WALKING PLANTS

On other planets the boundaries between plants and animals could be blurred, and you might have trees with beating hearts, or with feet to move to better positions as they compete for light and water. You could also have an animal that spends most of its time staying still, photosynthesising, only running away if threatened. Or a massive dinosaur-like creature that splays itself out on the ground to get nutrients directly from the soil, and obtains extra energy with the help of photosynthesising plants on its back.

MEGA CREATURES

Cooperation could lead to some fascinating creatures, such as a sea of amoebae acting as single jelly-like mega-creature, thousands of voracious shrimp-like carnivores forming a single organism that devours anything in its way, or a web of intertwined trees that collect water in wide pitchers at the top of their canopies. Similar entities do exist on Earth: for example, the world's largest organism is a 43-hectare forest of aspen trees in Utah, comprised of about 47,000 genetically identical stems, and one massive root system.



► NASA is preparing a mission to Europa for a 2023-24 launch, and is backing a private endeavour to reach Enceladus and study signs of life there. Meanwhile, the European Space Agency is hoping to launch a mission to Jupiter and its moons Ganymede, Callisto and Europa in 2022.

There is early evidence that those moons have oceans of liquid water deep under their icy crusts. This has raised hopes that there might be life there, especially given that we see oases of unusual life in the extreme environments around hydrothermal vents at the bottom of our own oceans.

Indeed, *Natural History Of An Alien* suggested that entire ecosystems may be based around deep-sea thermal vents on Europa, with tall towers of bacteria powered by the warmth and nutrients from the vents rising high above the sea bed, and territorial fish-like grazers sucking the nutrients from those towers, and in turn being preyed upon by streamlined shark-like animals.

In principle, this vision might be possible, says Dimitar Sasselov, astronomy professor and director of the Harvard Origins of Life Initiative, US, a centre that supports multi-disciplinary research aimed at revealing if life is abundant in the Universe. But he adds that because there is less energy available in the dark ocean, so any complex life there would be expected to be

EXTREME ENDURANCE

Getting oxygen to muscles is a key determinant of an animal's endurance. Here on Earth, cephalopods like octopus use a copper-based molecule in their blood to shuttle oxygen, making them more sluggish than mammals and birds that use iron-based hemoglobin. Scientists have speculated about other types of oxygen transport that could make animals fitter: in atmospheres with more oxygen, we might see creatures that can fly without ever having to stop for a rest.



TINY, BLIND WORLDS

On cold planets and moons without much sunlight, such as the moons of Saturn and Jupiter, life might have to get by with chemosynthesis, giving them a more limited energy supply. This could still lead to similarly complex life, but on a much smaller scale: a miniature version of Earth's life. Also, in worlds without light, such as the depths of Enceladus's oceans, there might be little need to evolve eyes: whole worlds of creatures may exist that sense their environments using other means.



FLOATING WORLDS

On planets with denser atmospheres, animals and plants could reach dizzying heights more easily and essentially 'swim' in the air as a result of their higher buoyancy. Scientists have envisioned flying whales feasting on green clouds of algae, octopus-like creatures and balloon-like plants floating high, using sacs filled with hydrogen or methane, and trees and forests reaching 10 times the height of those on our planet.



much smaller. "You have to take anything from today's Earth and recent Earth history of complex life and just shrink it," he says. "Can you have exactly the same behaviour and the same level of complexity but 100 times smaller? Absolutely. What's wrong with a shark that's just 5cm long? Nothing."

Not everyone thinks life on those moons will be complex, though. "If there is life in the Solar System, it's probably microbial," says Dr Yael Kisel, support scientist at NASA's Ames Research Center. And scientists agree that most life in the Universe as a whole is likely to be microbial, especially given that for the majority of the history of life on Earth it has been microbial. "What does a typical alien look like? It's going to be a little blobby thing under a microscope," says Shostak.

That's not to say there won't also be complex, perhaps even sentient life. Any intelligent life might not look like us, though: even here on Earth, if you take a trip to the zoo, most animals there are highly related to you but don't look much like you. But as Shostak jokes, "If you ask trilobites: 'Hey, what do you think the aliens will look like?', they would probably figure they're going to look like trilobites."

In fact, highly advanced and intelligent life, if it exists, might be machine-based. "The majority of the intelligence in the Universe is probably

"HIGHLY ADVANCED AND INTELLIGENT LIFE, IF IT EXISTS, MIGHT BE MACHINE-BASED"

not soft and squishy biology," Shostak says. "The majority of the really smart staff in the Universe is going to be machinery." This vision of artificially intelligent, highly autonomous machine life featured in *Natural History Of An Alien*, imagining it travelling the Universe, analysing planets, and adapting to local conditions much quicker than any biological life ever could.

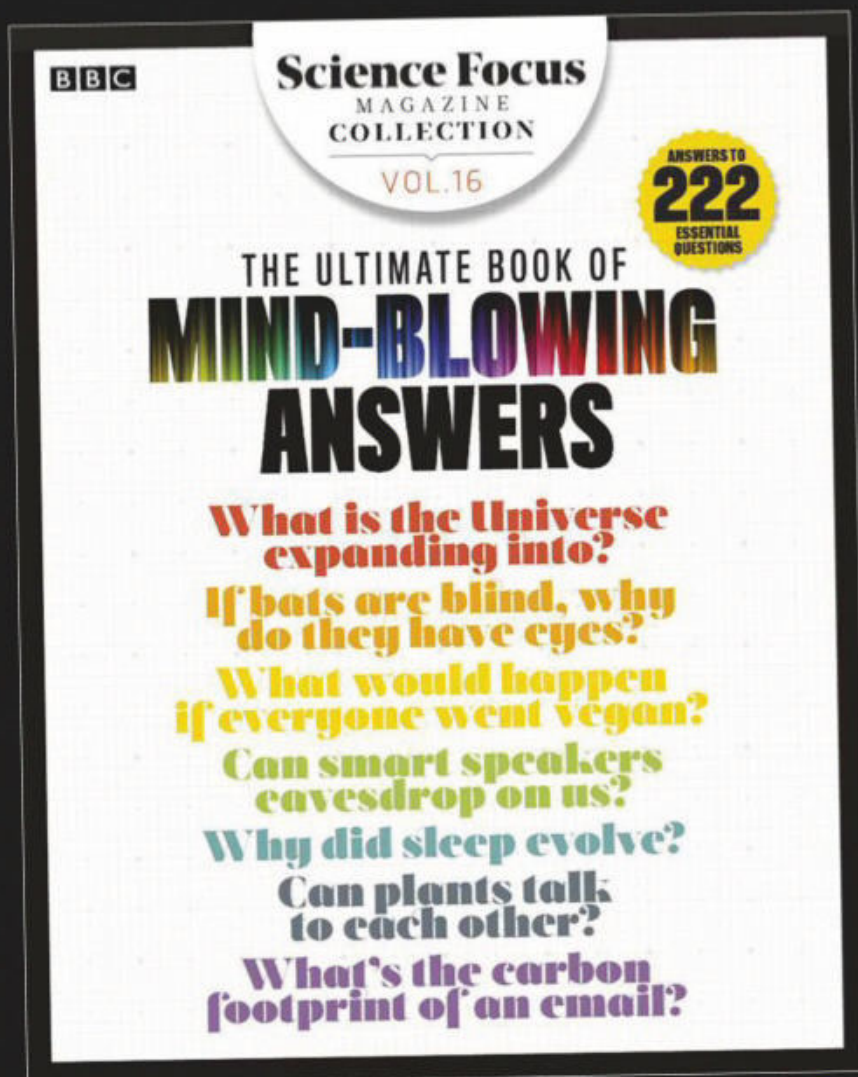
Whatever the case, life is most probably out there, many scientists believe. "Statistically, it's almost a certainty," says Fisher. And this means the search must go on, says Brinkman.

"We should continue to try – because if it were to get discovered, it would be the most important

by **MÍČO TATALOVIĆ**
Mičo is a science journalist based in London.

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- » What state of matter is fire: solid, liquid or gas?
- » If clouds can weigh tonnes, how do they stay aloft?

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Q
&
A

ALL YOUR
QUESTIONS
ANSWERED

GETTY IMAGES

THIS ISSUE’S EXPERTS

DR ALASTAIR GUNN Astronomer, astrophysicist	ALEX FRANKLIN-CHEUNG Environment/ climate expert	DR PETER J BENTLEY Computer scientist, author	PROF ALICE GREGORY Psychologist, sleep expert	DR HILARY GUITE Former GP, science writer	CHARLOTTE CORNEY Zoo director, conservationist
DR HELEN SCALES Oceans expert, science writer	DR CHRISTIAN JARRETT Neuroscientist, science writer	DR EMMA DAVIES Chemistry expert, science writer	LUIS VILLAZON Science/tech writer	JULES HOWARD Zoologist, science writer	PROF ROBERT MATTHEWS Physicist, science writer



REBECCA WALKER

WHY IS CURLY HAIR CURLY?

There are three contributing factors, all governed by your genetics. Firstly, the sac from which the hair grows (the ‘follicle’) is oval in shape, compared to straight hair’s more circular follicle. Next, curly hair exits the skin’s surface at more of an angle than straight hair, causing it to curve as it grows. Lastly, the shape of curly hair tends to result in more chemical bonds forming between protein molecules in the hair strand, which adds to the curliness. *HG*



Drosophila fruit fly:
much-loved by
geneticists

ADAM KING, HUDDERSFIELD

WHAT IS THE MINIMUM DIFFERENCE A SPECIES MUST SHOW IN ORDER TO BE CLASSED AS A NEW SPECIES?

This is less straightforward than it seems. The concept of species, as a way of classifying animals and plants, relies on finding some trait that all members of that species share, and which is unique to them. This works pretty well for many organisms, but species are continually being lumped together or split into two as biologists search for the perfect classification system. There are currently at least 26 different ways to define the concept of a species. Some consider physical or genetic similarity, while others consider whether populations

interbreed – or whether they *could* if they weren't separated by a geographical barrier, such as a mountain range or ocean. Other definitions of species focus on the evolutionary history of the organism, grouping species according to how recently they shared a common ancestor.

Even if biologists could agree on a single definition of a species, identifying a point at which a new species is created would still be difficult. Theoretically, the minimum difference could be a single mutated gene, marking a fork in the evolutionary tree where one species splits into two. However, biologists almost certainly wouldn't recognise the creation of the new species until later, when the genetic mutation manifested as a difference in the way the animal looked or behaved.

The closest we've come to this was probably in 2016, when researchers at the Janelia Research Campus in Virginia artificially altered the genome of a species of *Drosophila* fruit fly. This change to a single gene altered the frequency of the courtship 'song' produced by the male fly. The insects that carried this gene could still mate with the wild population, so they couldn't be considered a separate species by most definitions. But they preferred to mate with similarly mutated flies, and if this mutation had occurred in the wild, it's possible that this might have resulted in the evolution of a new species. **LV**

TOM OBERMEIER, VIA EMAIL

IF I'M LISTENING TO A PODCAST WHILE DRIVING, AM I DOING TWO THINGS AT ONCE?

Listening to a podcast is usually a passive enough activity that it leaves ample mental resources for you to do other things at the same time, including driving. This contrasts with when you're performing two tasks that are both mentally demanding – having a conversation while driving, for instance. In this case, both tasks require all (or nearly all) of your mental resources, so you are switching back and forth between the two, and probably doing both badly. Many studies have shown that, whereas conducting a phone conversation (even hands-free) has a detrimental effect on drivers' performance, listening to the radio does not. And when the driving does get more demanding – perhaps the traffic gets heavy – a University of Groningen study showed that drivers naturally disengage from or block out the radio or podcast to focus more on driving. **CJ**

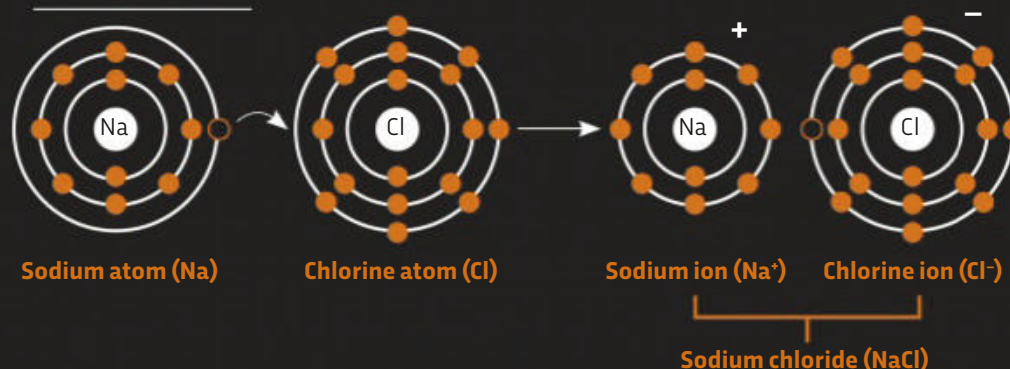
PAUL LAYFIELD, VIA EMAIL

HOW DO ATOMS 'KNOW' WHAT OTHER ATOMS TO BOND TO?

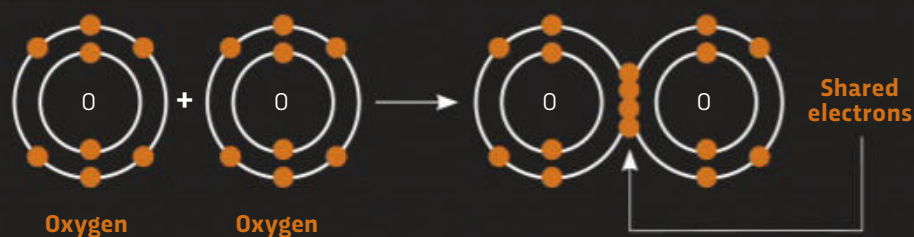
Atoms bond with each other in order to make their arrangement of negatively-charged electrons more stable. These electrons lie in so-called 'shells' around the positively charged nucleus, and each shell becomes stable once it contains a certain number of electrons, as dictated by quantum theory. Bonding allows atoms to achieve this stability by swapping or sharing electrons with other atoms until each has their shells filled.

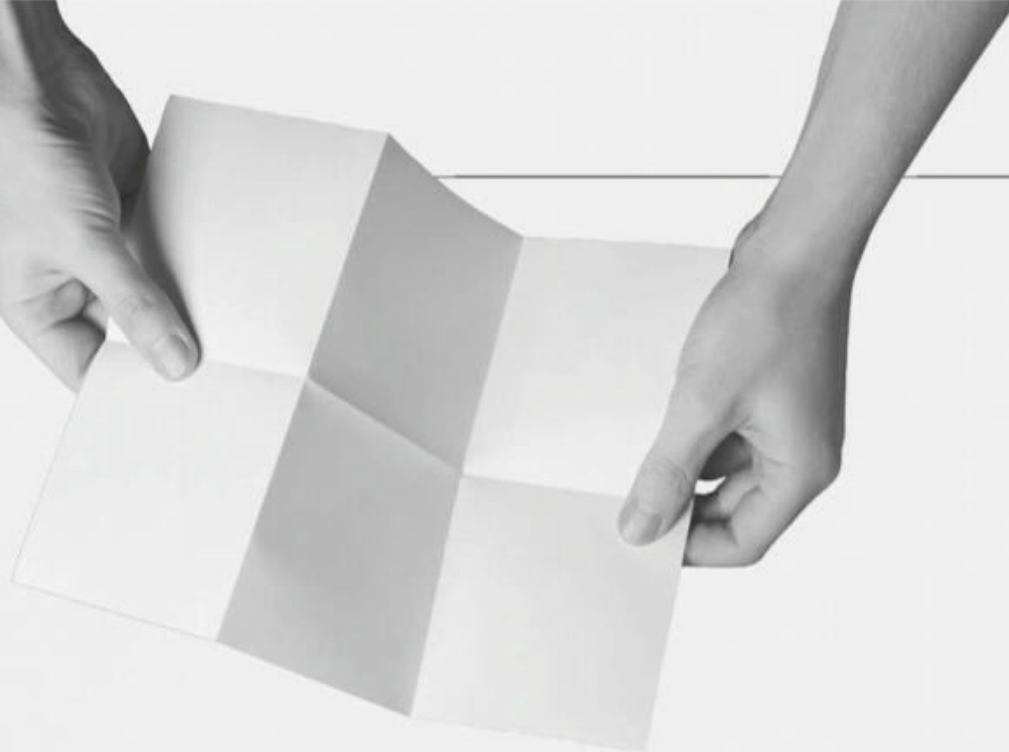
So, for example, sodium and chlorine atoms bond because the outer shell of sodium can become stable by losing an electron, while the latter can do so by gaining an electron. The two atoms are held together because losing an electron makes the sodium atom positively charged, while gaining an electron makes the chlorine atom negatively charged – and opposite charges attract. This is known as 'ionic bonding'. Another way of bonding is to share electrons – 'covalent bonding'. For example, oxygen atoms need two more electrons for their outer shells to become stable, and they can do this by sharing two electrons with another oxygen atom. Sharing then makes both atoms stable, and the resulting bond creates an oxygen molecule. **RM**

IONIC BONDING



COVALENT BONDING





ALICE SHERIDAN, ESSEX

WHAT'S THE MAXIMUM NUMBER OF TIMES THAT YOU CAN FOLD A PIECE OF PAPER?

Trying to fold an ordinary sheet of A4 paper suggests that even eight times is impossible: the number of layers doubles each time, and the paper rapidly gets too thick and too small to fold. Such 'geometric growth' effects are dramatic: in theory, 26 folds would make the paper thicker than the height of Mount Everest. The current world paper-folding record belongs to California high school student Britney Gallivan, who in 2002 managed to fold a 1.2km-long piece of tissue paper 12 times. **RM**

JULES SHIELDS, VIA EMAIL

IS IT POSSIBLE TO BE HEAVILY PREGNANT AND NOT REALISE?

Yes, and these so-called 'cryptic' pregnancies are not actually that rare. Around 1 in 500 pregnancies are not recognised until at least halfway through, and 1 in 2,500 not until labour starts. So how can a woman miss that she is pregnant?

One reason is that women sometimes continue to have light bleeding or 'spotting' during pregnancy, which could be mistaken for a period. This might be the regular 'withdrawal bleed' that happens when someone's taking the pill. Alternatively,

one-third of women in early pregnancy have spotting from the lining of their uterus or cervix. In some women, there are lower levels of the pregnancy hormone hCG (human chorionic gonadotropin), which means that the symptoms of pregnancy, such as nausea, are less marked. In these cases, the babies are often smaller in size, so the mother might not have such an obvious baby bump. Any symptoms that do occur might be misread as gastrointestinal or stress-related problems. **HG**



GETTY IMAGES X3 ILLUSTRATION: DAN BRIGHT

OLD WIVES' TALES...



YOU MUST WAIT AN HOUR AFTER EATING BEFORE GOING FOR A SWIM

For generations, parents have cautioned their children against swimming for an hour after eating – the common explanation being that the stomach is unable to cope with digesting food and the exertion of swimming at the same time, leading to stomach cramps that can cause the child to struggle in the water and drown. It sounds vaguely plausible, and back in the 1960s the American Red Cross advised against swimming straight after eating. Yet even at the time, there were suspicions it was nonsense.

In the late 1960s, several scientific studies took place in which swimmers were given meals at different times before going for a dip. They found no evidence of cramps. A few reported nausea and regurgitation, but nothing likely to prove life-threatening. In 2005, researchers in Australia found evidence that swimmers may increase their risk of experiencing a stitch if exercising fewer than two hours after a big meal, but there was no evidence of a major threat to health. In 2011, a review by an advisory panel of the American Red Cross of all the scientific evidence found that there is nothing to suggest that eating before swimming constitutes a risk of drowning, and concluded that the link "can be dismissed as a myth". **RM**

EXISTENTIAL FEAR OF THE MONTH...

MY CHAIR IS KILLING ME

Sixty years ago, researchers found that bus drivers had twice as many heart attacks as bus conductors. The difference was that the conductor was on his feet all day, whereas the driver was sitting down. Nowadays, adults in the UK commonly spend seven or more hours a day sitting down, and this tends to increase as people get older. Long periods of sitting are typically associated with an inactive lifestyle, which is a risk factor for heart disease, dementia and diabetes.

It's a vicious cycle because the collagen around your tendons and ligaments tends to harden when the joints aren't moving, and the postural muscles around your trunk gradually get weaker. This reduces your

flexibility and makes you more likely to strain your back or shoulders when you bend or lift. Without the need to support your weight, your leg bones become more porous and blood tends to pool in your ankles, which can lead to varicose veins and even deep vein thrombosis (dangerous blood clots in your veins).

The good news is that a 2016 analysis of studies of over a million people found that you can completely counter the negative effects of a desk job by doing 60 to 75 minutes of moderate physical exercise every day. Standing or walking during meetings and standing while talking on the phone are both good ways to start reducing your daily sitting time. *LV*



DILEEP BAGNALL and ANNA DACA, VIA EMAIL

HOW ARE BATTERIES RECYCLED?

In the UK, the most widely recycled battery is the lead-acid type that we use in our cars. These are broken apart in a hammer mill, the sulphuric acid drained off, and the lead and plastic separated in a water bath. Once collected, these are melted and used to form new batteries, while the acid is converted into industrial chemicals or water. A similar mechanical separation process is used to extract and reuse the zinc, manganese, steel and other components from alkaline batteries (such as AA and AAA). On the other hand, current methods for recycling lithium batteries are inefficient – it's cheaper to make new batteries than recover the lithium and cobalt from old ones. This is expected to change with the growing popularity of electric vehicles, which will help to fuel new research into lithium battery recycling methods. *RM*

20

The width, in kilometres, of an asteroid impact crater found under the sea off the northwestern coast of Scotland – the biggest ever found in the UK. It is believed that the impact occurred 1.2 billion years ago.

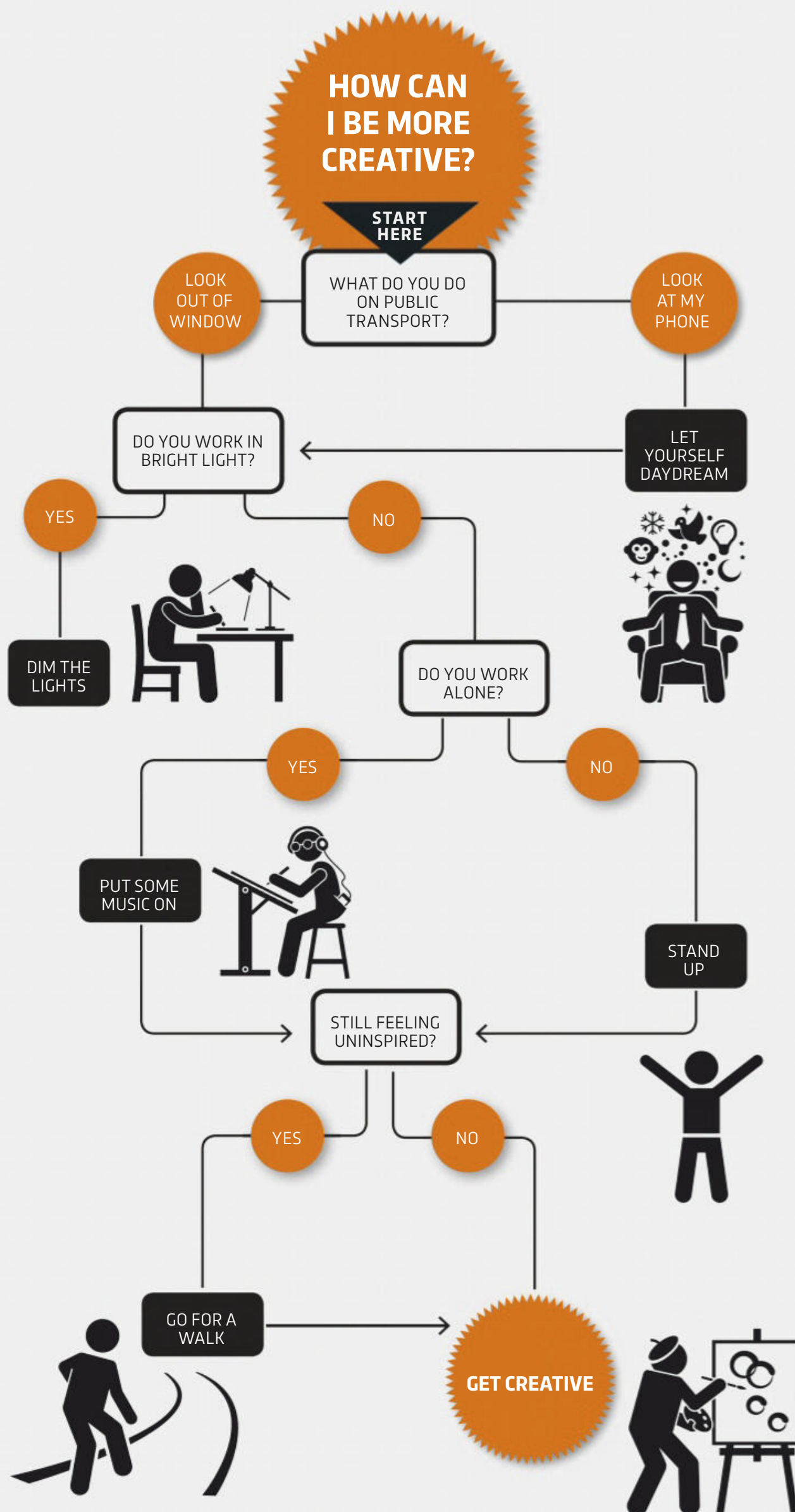
ALGORITHM YOUR LIFE

DAISY JOY, BRECON

DOES A BATH HELP YOU BURN CALORIES?

A 2017 study at Loughborough University did indeed find that a hot bath increases your metabolic rate slightly. As your core temperature rises, your heart has to pump harder to send warm blood to your skin in an attempt to stay cool, and your body also uses energy manufacturing special 'heat-shock' proteins that try to reduce damage to your cells from the higher temperatures. It's a pretty slow way to shed the pounds, though. An hour in a hot bath burns an extra 61kcal compared with just sitting down. That's less than the calories in one digestive biscuit. If you spend that hour doing anything remotely active, you'll burn more calories. Go for a walk, and you'll burn the same amount in 15 minutes. **LV**

GETTY IMAGES ILLUSTRATION: DAN BRIGHT



LET YOURSELF DAYDREAM

Boredom can be good, as it allows the mind to wander and 'freestyle'. A 2014 study at the University of Central Lancashire found that people performed better at creative problem-solving tasks if they did something boring first.

DIM THE LIGHTS

In 2013, researchers in Germany found that dim lighting removes mental constraints and encourages a riskier, more exploratory way of thinking.

PUT SOME MUSIC ON

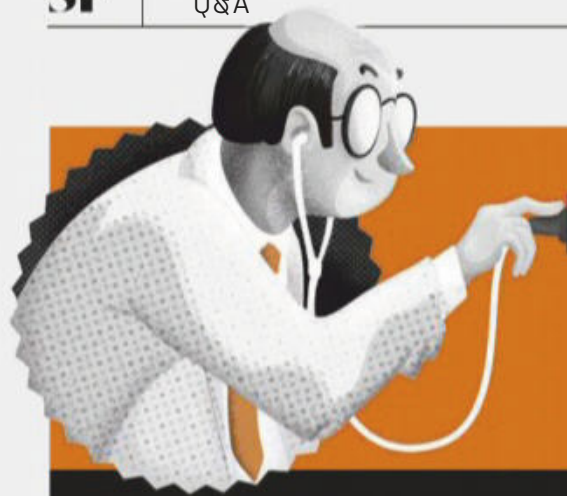
It's hard to concentrate if background noise is too loud. But research in 2012 found that 70 decibels of background noise (the volume of a normal radio or TV) can boost creativity. The background noise seems to promote more abstract reasoning.

STAND UP

Standing up in meetings creates a sense of excitement and information-sharing, and reduces the 'territorial' tendency to push your own idea over everyone else's. Researchers at Washington University in St Louis found that this increased the creativity of group decisions.

GO FOR A WALK

Steve Jobs frequently held walking meetings, and a 2014 study at Stanford University suggests that even walking on a treadmill will give a creativity boost. The reasons for this aren't clear, but it may be because light physical exercise increases blood flow and improves mood.



DEAR DOCTOR...

DELICATE ISSUES DEALT WITH
BY *SCIENCE FOCUS* EXPERTS

I'D LIKE TO LEARN A LANGUAGE TO IMPRESS MY NEW PARTNER. WHAT'S THE EASIEST ONE TO PICK UP?

According to the US Foreign Service Institute, which trains US diplomats, there are 10 'category 1' languages that share the most similarities with English, and are hence the easiest to learn. These include French, Spanish and Italian, and they all take about 600 hours of study to become reasonably fluent. If you want to really impress, though, why not try Afrikaans? This is also category 1 and is more unusual as a second language. Alternatively, you could impress your partner with your earning potential and learn a programming language. Ruby is one of the easiest languages for novice coders and one of the highest paid. Programmers fluent in Ruby typically earn £79,000. *LV*

I WAKE UP AT 4AM EVERY MORNING AND CAN'T GET BACK TO SLEEP. WHAT CAN I DO TO FALL ASLEEP AGAIN?

Early morning waking without the ability to return to sleep can be a symptom of insomnia. The recommended treatment here is usually 'cognitive behavioural therapy for insomnia' (CBT-I), in which people learn that, when unable to sleep, you should get out of bed and, if possible, do something relaxing such as reading or listening to soothing music until you feel sleepy again. Relaxation techniques, including mindfulness and muscle relaxation, can be incorporated too. Some people wake up early for different reasons, though, such as a condition known as 'advanced sleep phase

disorder'. It's important to discuss any sleep concerns with a healthcare provider before making a diagnosis and treatment plan. *AGr*

WHY DO I HAVE AN IRRATIONAL FEAR OF CRUMPETS?



It sounds like you are probably a 'trypophobe' – that is, someone with an irrational fear of clusters of holes or bumps, like you find on the surface of lotus seed pods, freshly frothed coffee, honeycomb, and, yes, crumpets!

This isn't a condition that's been officially recognised by psychiatry yet, but research has exploded in recent years, largely since a 2013 paper by two University of Essex psychologists, which described the condition and showed that it was caused by images that share a similar clustered pattern. According to these researchers, trypophobes can experience shivers, itchiness, skin crawling and/or nausea when they look at clusters of holes, and sometimes feel panicky and like they want to scream and destroy the holes. The Essex group thinks trypophobia could be an evolutionary hangover related to the fact that some dangerous animals, such as certain snakes and frogs, have a similarly clustered pattern on their skin. Other researchers in Japan have put forward a theory based on the idea that the condition reflects an oversensitivity to patterns that resemble various skin diseases.

Today, there are communities of trypophobes on sites such as Facebook and Reddit. These feature images that trypophobes (roughly 15 per cent of us, by some estimates) find powerfully triggering – so browse with caution. *CJ*

SAM STONEFIELD,
VIA EMAIL

IS IT THEORETICALLY POSSIBLE TO CREATE A WORMHOLE ON EARTH?

In 1935, Albert Einstein and his colleague Nathan Rosen showed that black holes can theoretically be connected via 'wormholes' – shortcuts through space and time that could link up black holes light-years apart. To create a wormhole on Earth, we'd first need a black hole. This is problematic: creating a black hole just a centimetre across would require crushing a mass roughly equal to that of the Earth down to this tiny size. Plus, in the 1960s theorists showed that wormholes would be incredibly unstable. It could be possible to stabilise the wormhole using so-called 'exotic matter', whose existence is predicted by quantum theory. This weird stuff is expected to have an antigravitational effect, which could stop the wormhole collapsing. But no one has a clue how to do any of this. And even if they did, it might all be pointless: theorists now suspect that travelling via wormholes would actually take longer than simply taking the conventional route through space. *RM*

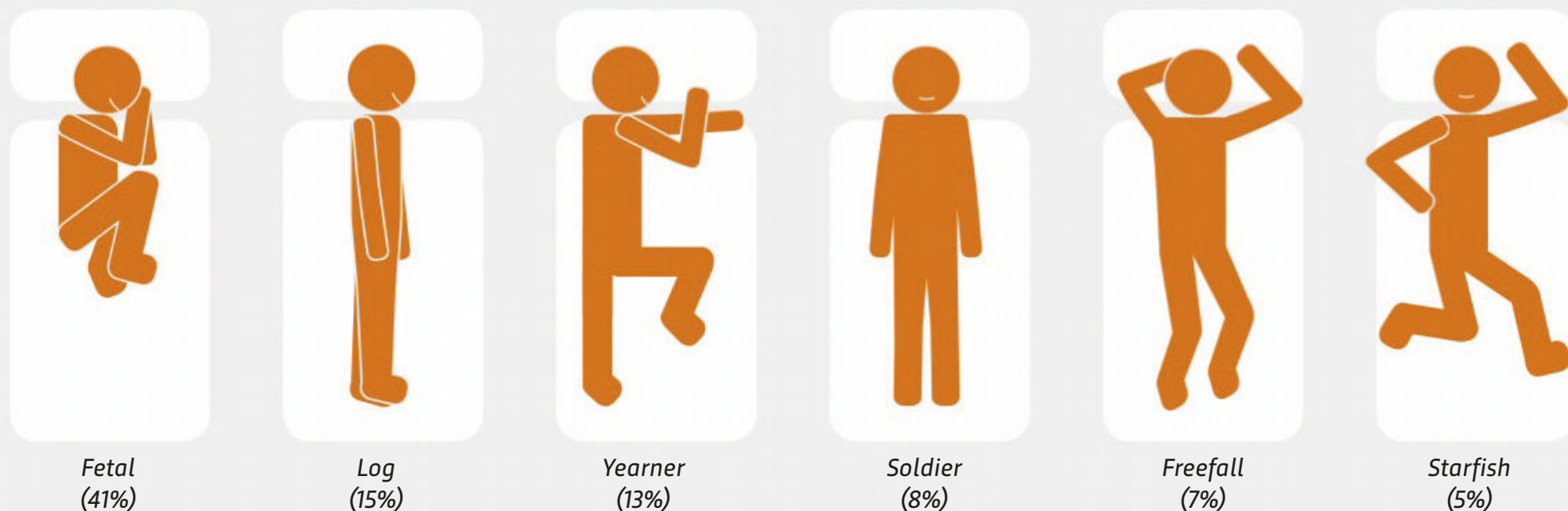
DONNA MILNE, BURTON-UPON-TRENT

ARE OUR SLEEPING POSITIONS LINKED TO OUR PERSONALITIES?

The research so far is mixed. In 2014, a study by psychologist Prof Richard Wiseman found that creative people tend to lie on their left side, and extroverts report sleeping close to their partners. A 2002 study in the US also found that people who start the night in the prone position (lying flat on their chest, also known as 'freefall') are generally more anxious and less

self-confident than those who sleep in other positions. But a 2012 study from researchers at West Chester University in the US noted just weak associations between sleeping position and personality, and flagged inconsistencies between studies. So we need more high-quality research before drawing any firm conclusions on this one. **AGr**

SIX MOST COMMON SLEEPING POSITIONS



NATURE'S WEIRDEST CREATURES...

THE SATANIC LEAF-TAILED GECKO

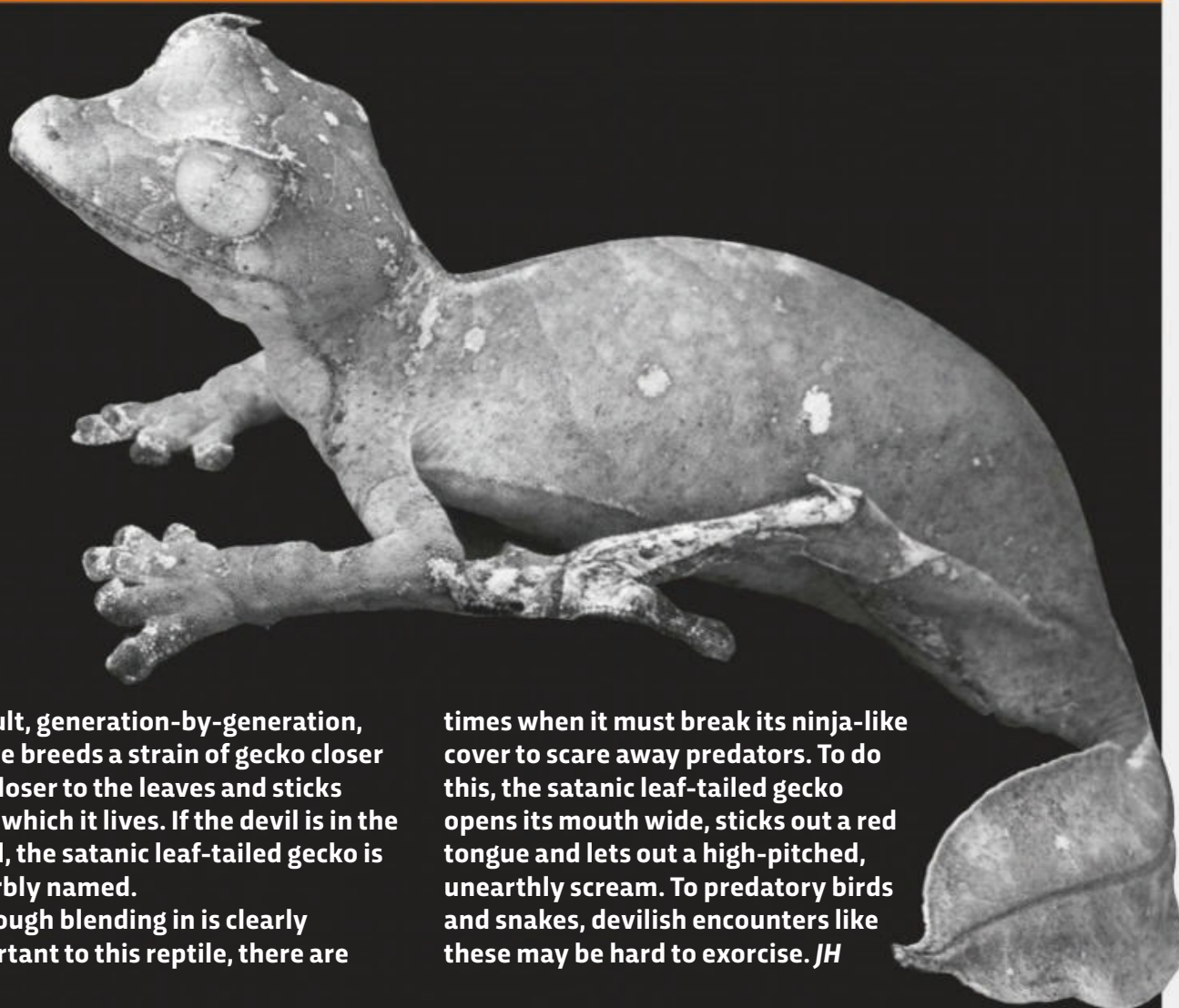
The satanic leaf-tailed gecko takes the idea of camouflage to new, and frankly absurd, levels. First, it possesses eyebrow horns that look like thorny twigs. Second, its skin is covered with artificial ridges that mimic leaf veins. Upon its back it has splotches of green that resemble lichens and mosses. And lastly, as if that's not enough, it has a tail that looks like a decomposing leaf.

An animal's camouflage is a measure of the environment in which it evolves. The Madagascan rainforests that this gecko calls home are chock-full of predators such as snakes and birds, which means that only the best camouflage variations persist. As

a result, generation-by-generation, nature breeds a strain of gecko closer and closer to the leaves and sticks upon which it lives. If the devil is in the detail, the satanic leaf-tailed gecko is superbly named.

Though blending in is clearly important to this reptile, there are

times when it must break its ninja-like cover to scare away predators. To do this, the satanic leaf-tailed gecko opens its mouth wide, sticks out a red tongue and lets out a high-pitched, unearthly scream. To predatory birds and snakes, devilish encounters like these may be hard to exorcise. **JH**



WHAT CONNECTS

SUNSHINE
AND HIPPOS?

1. By the time it's been filtered by Earth's atmosphere, ultraviolet rays make up only 3 per cent of the energy in sunshine. That's still enough to burn exposed skin, though.



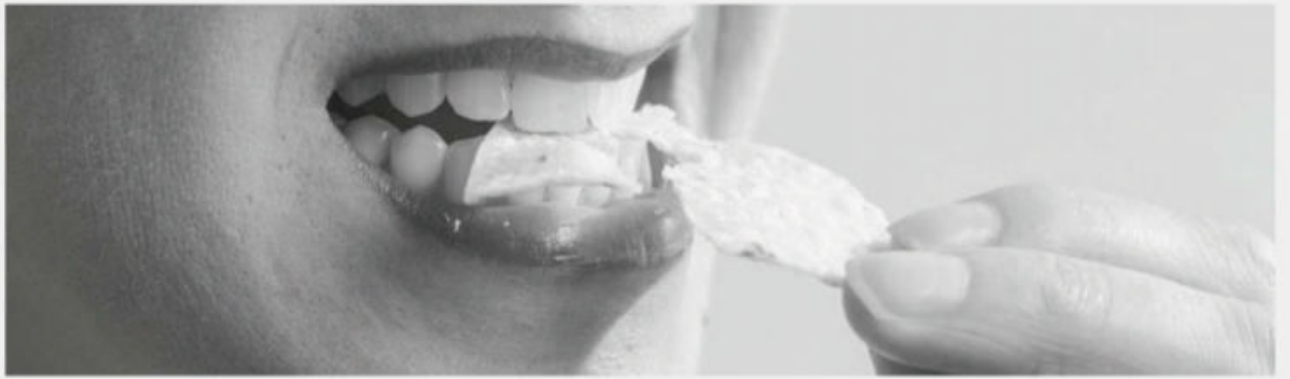
2. Sunburn is primarily caused by the shorter ultraviolet wavelengths (UVB), which disrupt the chemical bonds in the skin cells' DNA, triggering inflammation and skin peeling.



3. Sunscreens prevent sunburn by either absorbing or reflecting UV radiation. Sunscreens in the UK are given a 'sun protection factor' (SPF), which measures their ability to protect against UVB.



4. Hippos sweat a reddish, acidic chemical that acts as a natural sun cream by absorbing UV radiation. Collecting this from live hippos is difficult, but synthetic hippo sweat may be useful for creating sunscreens of the future.



TOM LEONARD, LETCHWORTH

HOW CAN MEAT-
FLAVOURED CRISPS
BE VEGETARIAN?

Many meat-flavoured crisps are vegetarian. In 2013, crisps giant Walkers sparked outrage when they added real meat extracts to their smoky bacon and roast chicken flavour crisps. They reverted back to vegetarian flavourings in 2016.

Cooked meat's flavour mainly comes from the browning process, when amino acids in the meat protein react with naturally occurring sugars to give a host of flavour chemicals. Vegetarian meat flavourings can be made in the lab by replicating this so-called 'Maillard reaction', using amino acids from plants, such as L-cysteine. **ED**

OLIVER NEAL, OXFORD

IS THERE A CURE
FOR MISOPHONIA?

Misophonia is a condition, only recently identified by psychologists, in which people feel angry, irritated and/or disgusted by human-generated sounds, such as chewing, slurping, breathing or tapping. It's early days, but preliminary studies suggest that cognitive behavioural therapy (CBT) – based around learning not to pay attention to the sounds and practising relaxing when hearing them – can be effective. Promising results have also come from a treatment approach based around acceptance and commitment therapy (ACT), part of which involves practising describing the triggering situation (such as a person eating) to oneself in a factual, non-judgmental way. **CJ**



TAMSIN NICHOLSON, VIA EMAIL

HOW DOES PLASTIC GET INTO THE OCEANS?

Around 80 per cent of the plastic waste found in the oceans today originated inland. Littering, poor waste management and industrial activity can all allow plastic to enter the natural environment. A significant proportion of this then blows into rivers and streams, which carry it into the ocean. This is particularly common in countries where waste infrastructure is lacking: an estimated two billion people worldwide

don't have access to solid waste collection. On top of this, wastewater from our homes often contains tiny pieces of plastic, including microbeads from cosmetics (now banned in the UK) and fibres from polyester clothing. Tackling plastic pollution therefore requires individuals, governments and companies across the globe to work together to reduce plastic consumption and waste. **AFC**



JENNIFER ARMSTRONG, MAIDSTONE

HOW DOES COLOUR-CHANGE LIPSTICK WORK?

Despite the marketing, colour change has absolutely nothing to do with mood and everything to do with acidity (pH). The lipsticks contain dyes that act a bit like litmus paper, the acidity indicator beloved of school chemistry teachers. Inside the lipstick, the dyes are colourless, weak acids. But lips have a higher pH than the lipstick, which triggers a chemical reaction that converts the acids into a strongly coloured compound.

The exact lipstick colour will depend on the skin's pH, which is in turn affected by physiological factors such as physical activity and hormone fluctuations. Our underlying natural lip colour also subtly affects the final lipstick shade. **ED**

DARREN MCPHEE, LONDON

WHY DOES COLA TASTE NICER OUT OF A GLASS BOTTLE?

While it's theoretically possible that the polymers used in plastic bottles, and to line aluminium cans, are leaching chemicals into the cola, the concentrations are probably too low to affect the taste. It could also be likely that a psychological effect is at play. The glass bottle was the original way of drinking cola, and so it's probably linked in our minds (via films and adverts) to that straight-out-of-the-fridge, all-American taste. **LV**

LOUIE BRIDGEMAN-RIVETT, BRIGHTON AND HOVE

DO ANY OTHER ANIMALS HAVE BABY TEETH AND ADULT TEETH?

Emphatically, yes: baby teeth are common in nearly all other mammals. The trait is almost certain to have been inherited from a single wobbly-toothed mammal ancestor that lived in the age of dinosaurs. The adaptation means that, as mammal jaws grow into adulthood, the adult skull is not left with tiny teeth incapable of biting and chewing. In most mammals, baby teeth are often swallowed and come out in their droppings undigested. **JH**



QUESTION OF THE MONTH

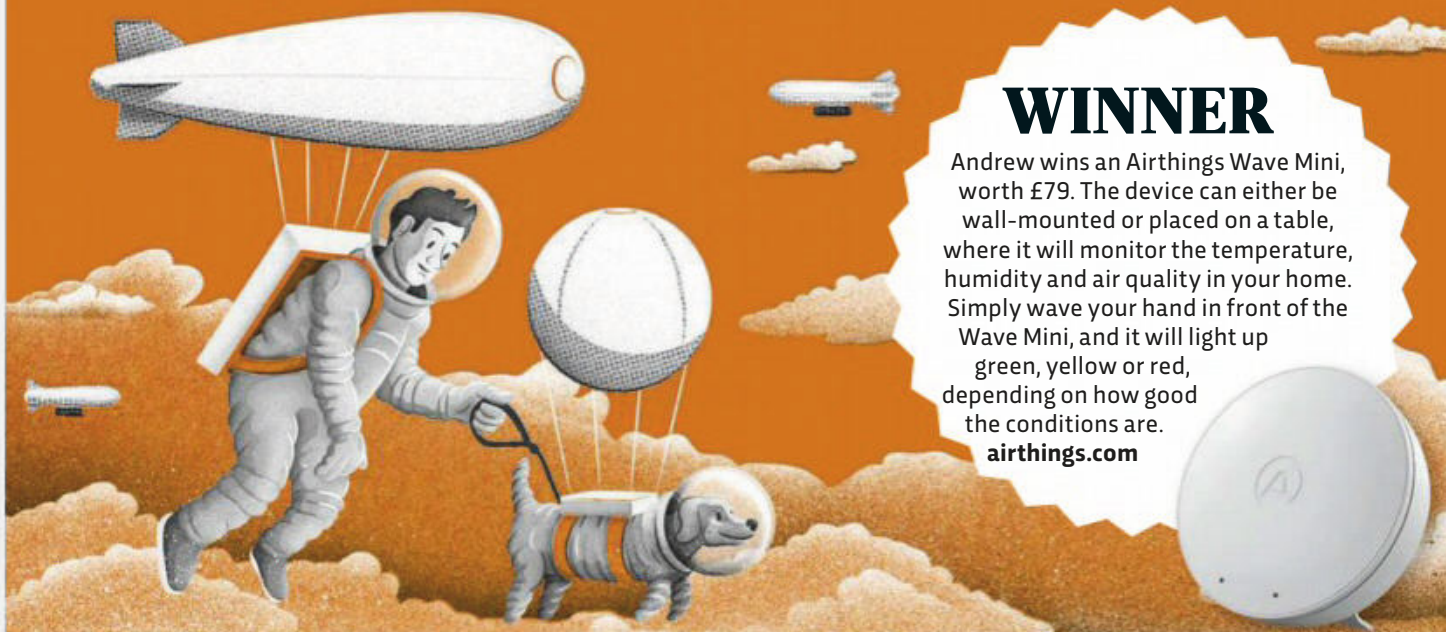
ANDREW CIREL, CORSHAM

COULD WE LIVE ON AIRSHIPS IN THE ATMOSPHERE OF VENUS?

Although the surface environment of Venus is extremely hostile, there is a region between about 50km and 60km above the surface where

the atmospheric pressure and temperature are similar to Earth's. In fact, this region may well be the most 'Earth-like' environment in the Solar System. This has inspired the idea of vast floating cities occupying the Venusian atmosphere, without the potentially more difficult and costly process of 'terraforming' the planet below for human habitation. However, space agencies have so far been

primarily focused on the possibility of colonising Mars instead. This is partly because Mars already receives much more attention as a destination for unmanned exploration, partly because living in floating cities may be perceived as inherently more dangerous, and partly because we humans have become used to living on *terra firma*. So it looks like a life amid the clouds will be consigned to sci-fi for now. **AGu**



WINNER

Andrew wins an Airthings Wave Mini, worth £79. The device can either be wall-mounted or placed on a table, where it will monitor the temperature, humidity and air quality in your home. Simply wave your hand in front of the Wave Mini, and it will light up green, yellow or red, depending on how good the conditions are. **airthings.com**



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RADAR

WHAT'S LIGHTING UP OUR ANTENNA THIS MONTH



1

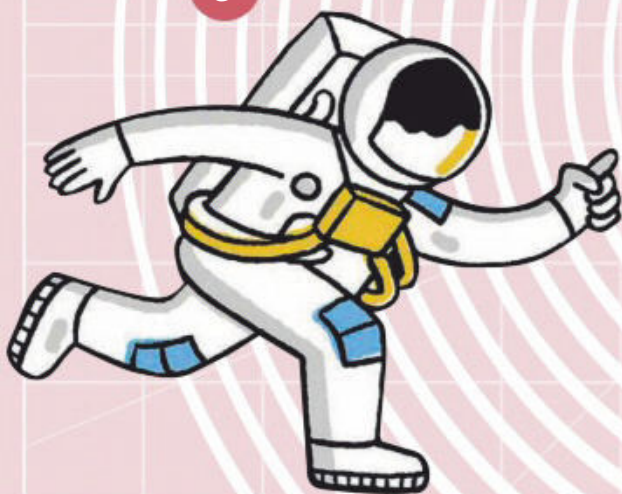


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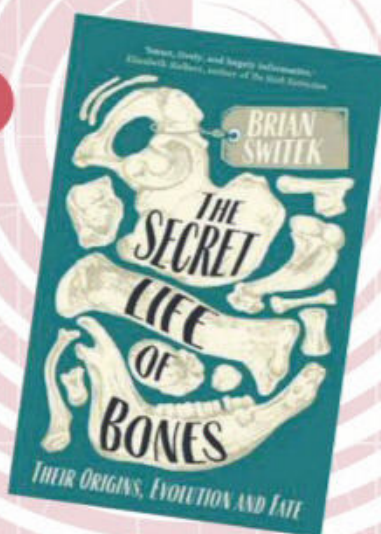
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3



5



6



1. Sci-fi film

Watch *The Iron Giant* at Ulster Museum Theatre this Cinema Day and join a robotic workshop for 6- to 12-year-olds. The beautifully animated film sees an extraterrestrial robot land in 1950s America.

Monday 26 August
nisciencefestival.com

2. Game on

Revisit your youth with popular games from the last 40 years. Spend 90 minutes with the SNES, or while away half a day with the Wii at one of the adult-only sessions at the Science and Industry Museum.

Power UP
bit.ly/sci_ind_mus

3. Family physics

Find out more about our closest neighbour in this interactive exhibition from the Institute of Physics. Discover the future of humans on the Moon, and the stories behind Apollo.

The Moon Adventure
Until 30 August
iop.org/moon

4. Time for action

Experience rewinding in augmented reality, discover the journey our foods take to reach our plate and join artists at We The Curious as they consider what we'd need to build a house on Mars.

Climate Action!
Until 1 September
wethecurious.org

5. On bones

Publishing this month, *The Secret Life Of Bones* is an exploration of the story of our skeleton, with cameos from other vertebrates including dinosaurs, sabretooth cats and our own ancestors.

Out 8 August
duckworthbooks.co.uk

6. Race science

Authors and journalists, including Angela Saini, discuss *What Does Race Science Look Like In The 21st Century?* They also examine what lies beneath the rising scientific research into racial differences.

28 August
sciencemuseum.org.uk

Did you know that the new Raspberry Pi offers **40x the performance** of the original model? p93



2,600



The age, in years, of an ancient Babylonian tablet, that references sunspots. p91

Profile

A SOLAR EXPLORATION

AS THE SUN EXHIBITION ARRIVES AT MANCHESTER'S SCIENCE AND INDUSTRY MUSEUM, WE CAUGHT UP WITH ONE OF THE CURATORS, LEWIS POLLARD, TO FIND OUT HOW THE EXHIBITION TAKES VISITORS CLOSER TO THE SUN

WHY ARE WE SO FASCINATED BY THE SUN?

Throughout human history, people have interpreted the movement of the Sun in different ways and used that to try and make sense of their place in the Universe.

One object on show in *The Sun* is a Babylonian tablet, on loan to us from the British Museum [see box, opposite page]. Written on it is one of the earliest known references to what might be features on the surface of the Sun – 2,600 years ago someone observed the Sun and wrote on the tablet that if you see white spots on its surface, then it could be a sign that a famine will happen soon. We now know about sunspots and the potential dangers of high-intensity solar storms, especially on today's communication technologies. Seeing someone report the same sort of idea all those years ago is really amazing.

The Trundholm sun chariot, from 1400 BC, is also on display in the exhibition. It shows the Scandinavian Bronze Age belief that the Sun is carried across the sky on the back of a horse-drawn chariot. You find that loads of religions use everyday examples – animals, boats, carts – to make sense of what the Sun is doing, and how it moves across the sky.

THE EXHIBIT DOESN'T ONLY LOOK TO THE PAST. WHAT DOES IT TELL US ABOUT THE FUTURE?

All energy from Earth is ultimately derived from the Sun in one form or another. We have harvested energy



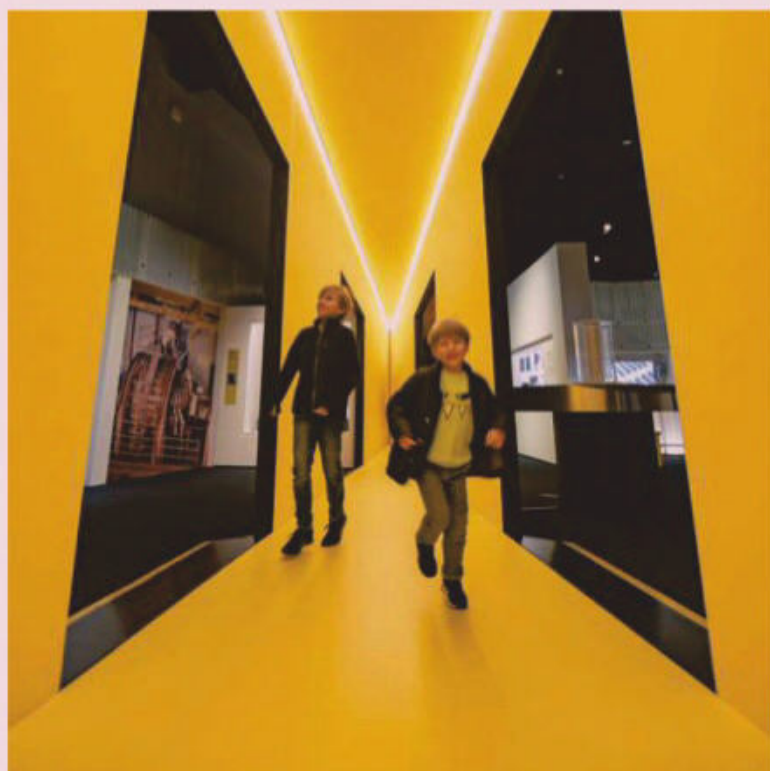
“We have a virtual reality experience, called Space Descent VR. You experience coming back down to Earth from the International Space Station”

from the Sun throughout history, from fossil fuels, which are fossilised plants and animals that derived their energy ultimately from the Sun, to more direct solar technologies. One object in the exhibition is a solar-thermal generator that was installed on the roof of the White House in 1979 under US President Jimmy Carter.

Looking at the technologies advancing our ability to capture the energy of the Sun, we consider if these could be the solar revolution that we'll see on the Earth. Or, will the solution be to recreate the conditions of the Sun here on Earth? Tokamak Energy's tokamak fusion reactor is an



LEFT: Images of sunspots, represented at different wavelengths



ABOVE: Visitors can run along a 'sunbeam' at the exhibition

BELOW LEFT: Lewis Pollard

experimental nuclear fusion reactor that aims to recreate how the Sun works, and so derive energy from that. We have a small version of the tokamak in the exhibit [see box, right] and it's a really impressive object to see. It's made of stainless steel and circular – it looks quite sci fi.

HOW HAS NEW TECHNOLOGY SHAPED THE EXHIBITION?

We have a lot of amazing immersive, interactive experiences. In one, you stand in this array of light to see how shadows move across sundials, and how they were used to tell time before we had mechanical clocks. There are augmented reality screens where visitors can digitally try on sunglasses and of course, the grand finale of the exhibit: an interactive solar storm. That is a really immersive, awe-inspiring experience.

HOW DID YOU GO ABOUT CREATING THE EXPERIENCE OF THE SOLAR STORM?

Visitors spend the exhibition learning about the Sun and reflecting on their relationship with it. This final, huge spectacle drives home the extent of the impact of the Sun on our lives.

You enter a room with a large screen. Projected on the screen is imagery taken from NASA's Solar Dynamics Observatory satellite, which observed the Sun over a long

period of time. It's presented in an eight minute movie and it has this big, impactful soundscape as well.

For a lot of people, this will be, metaphorically, the closest to the Sun they will ever be. We wanted this exhibition to have a big impact, for it to be more than just us talking about a topic; we wanted to bring the Sun closer to people.

ARE NEW TECHNOLOGIES – LIKE AUGMENTED REALITY, VR AND SO ON – CHANGING THE WAY YOU CURATE EXHIBITIONS?

I think increasingly so. The possibilities are really amazing for what we can do using these technologies.

We have a virtual reality experience, called Space Descent VR, narrated by British astronaut Tim Peake. You put on the headset and experience coming back down to Earth from the International Space Station. That has a completely different impact than it would if you were just reading it or just hearing about it. These technologies are offering potential new ways to get our messages across and have a greater impact for our visitors. So, I'm excited to see how these technologies evolve.

Of course, all of these technologies tend to come with their own challenges. They work better for some people and not for others – there's no one size fits all solution to anything. But one thing our museum does really well is making our galleries feel very interactive, usually through our explainers and our demonstrators. Having a real person talking to you, explaining and showing you how things work, has a huge impact.

IN A MUSEUM SETTING, WILL REAL PEOPLE EVER BE REPLACED BY TECHNOLOGY?

I hope not. For me, I always respond better to people. Especially people who are really passionate about what they're talking about, and we have an amazing team of volunteers who work across all of our different exhibitions. Talking to them, I think, really impacts on me as a museum visitor, even as a museum worker. So, I hope that never goes away. I think that's something that this museum does incredibly well, and I'm really proud of our volunteers and our staff who work with the public, face to face.

LEWIS POLLARD

Lewis is the associate curator at the Science and Industry Museum in Manchester. *Interviewed by BBC Science Focus editorial assistant Amy Barrett.*

DISCOVER MORE

The exhibition runs until 5 January 2020. Entry to the museum is free, but tickets to the exhibition cost £8 for adults. Children go free with a paying adult. Find out more at scienceandindustrymuseum.org.uk

IN THREE OBJECTS



BABYLONIAN TABLET FROM 750 BC

This ancient tablet is the earliest known reference to features on the Sun and shows the legacy of humankind's fascination with our star.



TOKAMAK REACTOR

This is a prototype nuclear fusion generator. It's just one example of the many attempts around the world at building an artificial Sun here on Earth.



BEACH PAVILION

As an exhibition about our relationship with the Sun, what better place to reflect on its impact on our lives than at an immersive beach pavilion?

Piece of the Pi

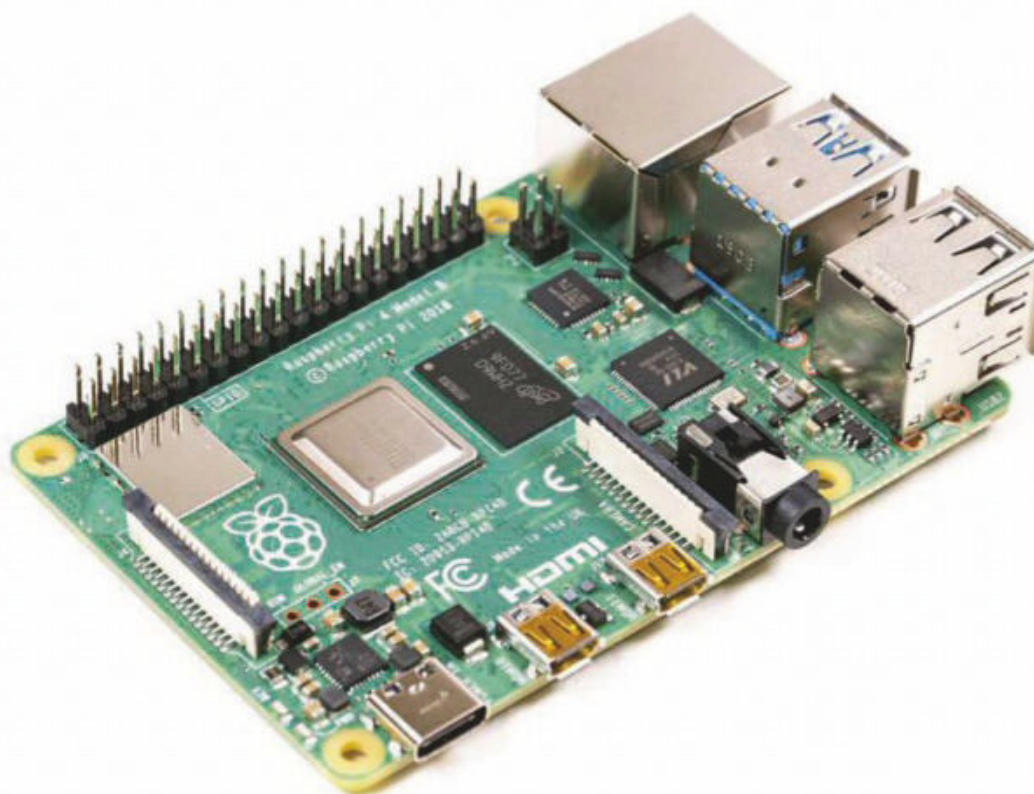
PICK UP A RASPBERRY PI AND TRY OUT THESE STARTER PROJECTS TO GET A TASTE OF THE CODING GOODNESS



DIY WEATHER STATION

A more advanced project for those looking for a challenge, this uses a variety of hardware to collect climate and environmental data, and some more advanced programming skills to boot. The project takes you through building a prototype, and then how to turn it into something more robust and reliable, should you want to deploy it outside.

bit.ly/pi_weatherstation



TWEETING BABBAGE

This project helps you to turn an old cuddly toy into a Twitter bot that can tweet photos to your Twitter feed at the press of a button. The project gets its name from the Raspberry Pi's official mascot, Babbage Bear, and uses the Python coding language, as well as a Raspberry Pi embedded in your stuffed toy of choice.

bit.ly/pibabbage



ROBOT BUGGY

This project will help you to build your own robot buggy that you can program with a handful of simple Python commands. You'll use a motor controller board and two motors, then build a robot chassis to house it all. Set yourself a challenge by creating a maze, and then program the robot to get around it unscathed.

bit.ly/pibuggy



PARENT DETECTOR

Add a Raspberry Pi camera module to your setup and you can create a simple video surveillance system, and even use a motion sensor module to trigger video recording when the camera detects movement in the room. Want to take it a step further? You can add a command to disable the red LED from the camera board, and make it extra stealthy.

bit.ly/piparentdetect



WHOOPI CUSHION

This brings the classic family pranking device bang up to date. You can program it to create whichever sound you choose, so the possibilities for raising a chuckle are endless. Making this teaches the basic programming constructs to create a simple program, using a handful of basic components – crocodile clips, a jumper lead and some speakers.

bit.ly/piwhoopi

Troubleshoot

RASPBERRY PI 4



THE CREDIT-CARD-SIZED COMPUTER IS BACK FOR A SIXTH GENERATION, AND IT'S FINALLY READY TO REPLACE YOUR DESKTOP PC. RASPBERRY PI'S CO-FOUNDER EBEN UPTON TELLS US MORE

WHAT WAS THE INSPIRATION BEHIND THE RASPBERRY PI?

The Raspberry Pi Foundation was founded 10 years ago in response to a decline in the amount of interest in studying computer science at universities in the UK. At Cambridge, we had seen the number fall by a factor of three, which is kind of a good measure of enthusiasm. We asked ourselves why that was, and we came to the conclusion it was because we weren't teaching computing in schools properly in the UK, and also that computing wasn't as accessible to young people as it once was. The Raspberry Pi and the Raspberry Pi Foundation was our attempt at tackling that problem.

WHAT WAS THE AIM?

I learnt to program on a BBC Micro. The computer was at school, and I just started poking at it. That's the description of 90 per cent of people of people between the ages of, say, 35 and 55, working in the computer industry in the UK right now. And that world of very programmable hardware went away.

Those machines were replaced in homes by games consoles and tablet computers. These are all amazingly powerful computers, but they're not designed to be programmed by their users. The only survivors of that really are the PC and the Mac, and they're a bit expensive, a bit intimidating and they don't tend to ship with development tools. The Raspberry Pi Foundation was started with the idea of creating a small, low cost, programmable, robust educational computer, that children could have in their bedroom and learn to program on.

AND NOW YOU'VE SOLD AROUND 27 MILLION OF THEM. WHY DO YOU THINK IT CAPTURED IMAGINATIONS?

There's an element of timing. On the educational side, it came along at a point where everyone realised how badly the computing curriculum was, and so it tapped into a cultural zeitgeist in that respect. I also think the UK was a particularly good place to do this, because we have a strong culture of computer hobbyists, and it resonated with them.

And then the real surprise for us was the industry uses. Probably half the units we sell go into industry, for industrial control automation and robotics. We set out to make an educational device for children, but you quickly learn that if you're making a device that's robust, friendly, performant and interesting for children, that it also ends up fitting a bunch of industrial applications.

TELL US ABOUT THE RASPBERRY PI 4.

The Raspberry Pi 4 is the sixth generation of Pi, and offers 40 times the performance of the original device. It now has enough memory that most users would find they could replace their desktop PC with a Raspberry Pi, and they wouldn't really notice the difference. Of course, we've retained the interfacing capabilities and hackability of the classic Raspberry Pi line, and the \$35 (£34) price point for the most basic model, which is important. It wasn't easy but we got there.



“When somebody sits on the plate, the Raspberry Pi detects this and plays a rude sound of your choosing”

HOW DO PEOPLE GET INVOLVED?

Pick up a Raspberry Pi and start playing! We have loads of product information and educational resources for both taught education and self directed learning on raspberrypi.org, as well as information to help people find a coding club in their area. Then we have the forums, where people can go and ask any questions. It's an enthusiastic community of all ability levels.

WHAT'S YOUR FAVOURITE FIRST PROJECT FOR PEOPLE TO TRY?

Well, it depends on your physical and mental age but the one that immediately springs to mind for me is the whoopee cushion (see opposite page). You basically line a couple of paper plates with tin foil, put them facing each other and connect a wire on each one. Then when somebody sits on the plate, the two contacts connect, the Raspberry Pi detects this and plays a rude sound of your choosing. It's a much loved project you can do it in five minutes and it never fails to raise a smile. And that, ultimately, is what Raspberry Pi is all about.

EBEN UPTON (@EbenUpton)

Eben is the creator of the Raspberry Pi and co-founder of the Raspberry Pi Foundation. He was appointed a CBE in 2016 for his services to business and education. **Interviewed by Verity Burns.**

RECOMMENDED

FIND OUT WHAT'S CAUGHT OUR ATTENTION THIS MONTH



WHAT I'M WATCHING
Daniel Bennett
EDITOR



THE GREAT HACK
NETFLIX AND SELECTED CINEMAS

Every time we use a piece of tech to help us get fit, find love, talk to our friends or, well, do anything, we leave behind a cookie crumb of data that tells the people in Silicon Valley a little more about us. What's the harm in that?

The answer to that question exploded into the public consciousness last year when *The Guardian* unravelled how the self-described "behaviour-change agency" Cambridge Analytica (CA) used Facebook profile data to help Donald Trump win the 2016 election. A whistleblower revealed how the company had taken data from Facebook, without permission, and used it to create a campaign that aimed to mobilise apathetic voters in swing states to tip the tables in Trump's favour.

This confusingly named documentary (there were never any actual hacks) follows the CA story, from its militaristic origins to the company's ultimate demise, to reveal the worrying ways our data has been politically 'weaponised'. Along the way the filmmakers try to better understand the people behind CA and question Facebook's actions following the data breach.

While there's little new insight or revelation for anyone who's followed

the story closely, the film does shine a light on the human story of CA, in particular how employee Brittany Kaiser ended up working on the Trump campaign after dedicating her early career to helping get Barack Obama and Hillary Clinton elected.

Hopefully this film brings the story to a new audience, and one day it will become a parable of what happens when we let tech companies run wild with our data. But the truth is, if little changes, *The Great Hack* is an unnerving insight into where the future of politics is headed.

meets Zinnia, a former teacher with something to hide.

The Warehouse raises questions about how much power and control we should allow one company to have. When a hugely profitable business says their aim is to build a better world, should we take them at their word? And how much are we willing to sacrifice for convenience?



WHAT I'M WATCHING
James Lloyd
STAFF WRITER



REVOLUTIONS: THE STORY OF SIX REMARKABLE INVENTIONS
BBC FOUR, TUESDAYS, 9PM

The ever-engaging Jim Al-Khalili returns to our screens this month with a fascinating series that tells the story of six game-changing inventions: the aeroplane, the car, the rocket, the smartphone, the telescope and the robot.

We follow the stories of the visionaries who transformed our world, peering into their original notebooks and sketches,

and tracing their creative process through dramatic reconstructions



WHAT I'M READING
Sara Rigby
ONLINE ASSISTANT



THE WAREHOUSE
BY ROB HART
(£12.99, TRANSWORLD)

Climate change has scorched the Earth, unemployment is rocketing, and the economy of the United States is in freefall. Paxton, a former small business owner, is left with no other choice than to apply for a job with the Cloud, the enormous online retailer which stepped into the void left as high street shopping was abandoned.

Despite his misgivings about the company, he moves into one of the Cloud's communities, called a Mother Cloud, which has all the amenities an employee needs, so that they never have to leave. There, he



and lovingly recreated experiments. There are familiar names (Galileo Galilei, Leonardo da Vinci), but also lesser-known pioneers such as Bertha Benz (she took the first long-distance car journey) and Ibn al-Haytham ('the father of modern optics').

Jim manages to find new mileage in even the most well-trodden of subjects. Take his episode on the invention of the aeroplane. We've all heard of the Wright brothers, but did you know about the 9th-Century scholar who strapped feathers to his arms and leapt off a cliff, or that the first human to fly in an untethered aeroplane was a 10-year-old boy?

Ultimately, we're reminded that the road to invention is never straightforward, but is an intrinsically human process, full of mistakes, fortune, tragedy, and sheer ingenuity.



WHAT I'M TESTING

Amy Barrett
EDITORIAL ASSISTANT



THE 500 AT LIMINA VR THEATRE

TICKETS COST £8, LIMINAIMMERSIVE.COM

It is unlikely that I will visit Ethiopia. Even if I could afford the travel costs, the flights alone would add 1.02 tonnes of CO₂ to my carbon footprint. My trip to Limina Immersive, on the other hand, involved a journey into Bristol on the Metrobus (powered by a mix of biogas and diesel) and the price of a ticket.

In return, I spent 12 minutes being guided by wolf-monitor Alo Hussein, scouring the Ethiopian mountains for one of the 500 remaining Ethiopian wolves. The cinema uses the VR

headset Oculus Go to immerse audiences in the documentary, which was created by VR innovators, Biome Productions. Alo narrates his day, introducing viewers to the wolf pack he is monitoring. The cubs call between themselves, and approach hesitantly. They sniff, inquisitive, and it is as if I could reach out and touch their wet snouts.

Alo explains that the spread of rabies means the wolf numbers are dwindling, while their habitat is threatened by the cattle farming that is a growing trade in Ethiopia. We join him and his daughter as they teach local farmers about the wolves, and vaccinate their dogs against the disease so it cannot be passed to the wolves, or to humans. Alo watches the Sun set over the plain, his day drawing to a close, and I am back in the cosy cinema room, in a reality slightly changed from the one I left.

At Limina Immersive, viewers can enjoy a variety of immersive VR shows, including a Cirque de Soleil performance (pictured above) and a dive on the Great Barrier Reef with Sir David Attenborough

DISCOVER MORE

SQUEEZE EXTRA JUICE OUT OF THE TOPICS IN THIS ISSUE OF *BBC SCIENCE FOCUS* WITH THESE BOOKS, WEBSITES AND SHOWS

Eye opener p6

VIRTUALLY THERE

Roncalli Circus Theatre sadly won't be visiting the UK any time in the near future, but you can experience the amazing holographic elements of the show online in this YouTube clip.

bit.ly/holo_circus

BERRY SMART

See the fruit-picking robot in action. Filmed by the team at the University of Plymouth, the Fieldwork Robotics arm demonstrates how efficiently and gently it collects ripe raspberries from a farm in West Sussex.

bit.ly/robot_picker

Primer p22

NEURALINK LAUNCH EVENT

Watch the launch event for Elon Musk's Neuralink technology, which was live-streamed on 16 July. The event doesn't actually start until 1 hour 30 minutes into the video, so you may want to skip ahead.

bit.ly/neuralink_launch

Shake a tail feather p40

STRICTLY, SPIDER-STYLE!

Be enthralled by a peacock spider's hypnotic dancing as he attempts to win over a female in this clip from the 2014 BBC wildlife series *Life Story*.

bit.ly/dancing_spider

Mass extinction p48

THE ENDS OF THE WORLD

BY PETER BRANNEN
(£10.99, ONEWORLD)

In this book – snappily subtitled *Volcanic Apocalypses, Lethal Oceans And Our Quest To Understand Earth's Past Mass Extinctions* – science journalist Brannen takes an in-depth look at how scientists are piecing together the complex story of Earth's previous five mass extinctions, and what their findings can tell us about our current predicament.

MASS EXTINCTIONS AND THE FUTURE OF LIFE ON EARTH

By way of dinosaurs and the dodo, palaeontologist Michael Benton offers his own perspective on the Earth's turbulent history in this TED talk.

bit.ly/mass_extinction

THE CRETACEOUS-PALAEOGENE MASS EXTINCTION: WHAT DO WE REALLY KNOW?

A 45-minute lecture on the extinction of the dinosaurs, presented by Dr François Therrie of the Royal Tyrrell Museum of Palaeontology in Alberta, Canada.

bit.ly/KPGextinction

What would alien life actually look like? p70

SO WHERE ARE THE ALIENS?

Seth Shostak, a senior astronomer at the SETI (Search for Extra-Terrestrial Intelligence) Institute, hosts this brilliant half-hour radio show from the World Service which talks to the leading scientists in the field, including Jill Tarter, whose life's work inspired the 1997 film *Contact*.

bit.ly/search_for_eti

ALIENS ON FILM

Francine Stock of *The Film Programme* and Adam Rutherford of *Inside Science* take a look at the ways that science has shaped the aliens we see on the silver screen.

bit.ly/alien_films

LIFE AS WE DO NOT KNOW IT

BY PETER WARD
(£10.99, VIKING)

First published in 2005, *Life As We Do Not Know It: The NASA Search For (And Synthesis Of) Alien Life* draws on NASA research and the origins of life on Earth to consider what extra-terrestrial life might look like, and how we define life itself.

A scientist's guide to life p98

FIGHTING AGAINST SMELLY ARMPITS

In this TEDx talk, Dr Chris Callewaert talks about the chemical characteristics of bacteria living in the armpits. He also discusses his own research, in which he helps stinky people smell sweeter by replacing their underarm bacteria with those of non-smelly volunteers.

bit.ly/dr_armpit

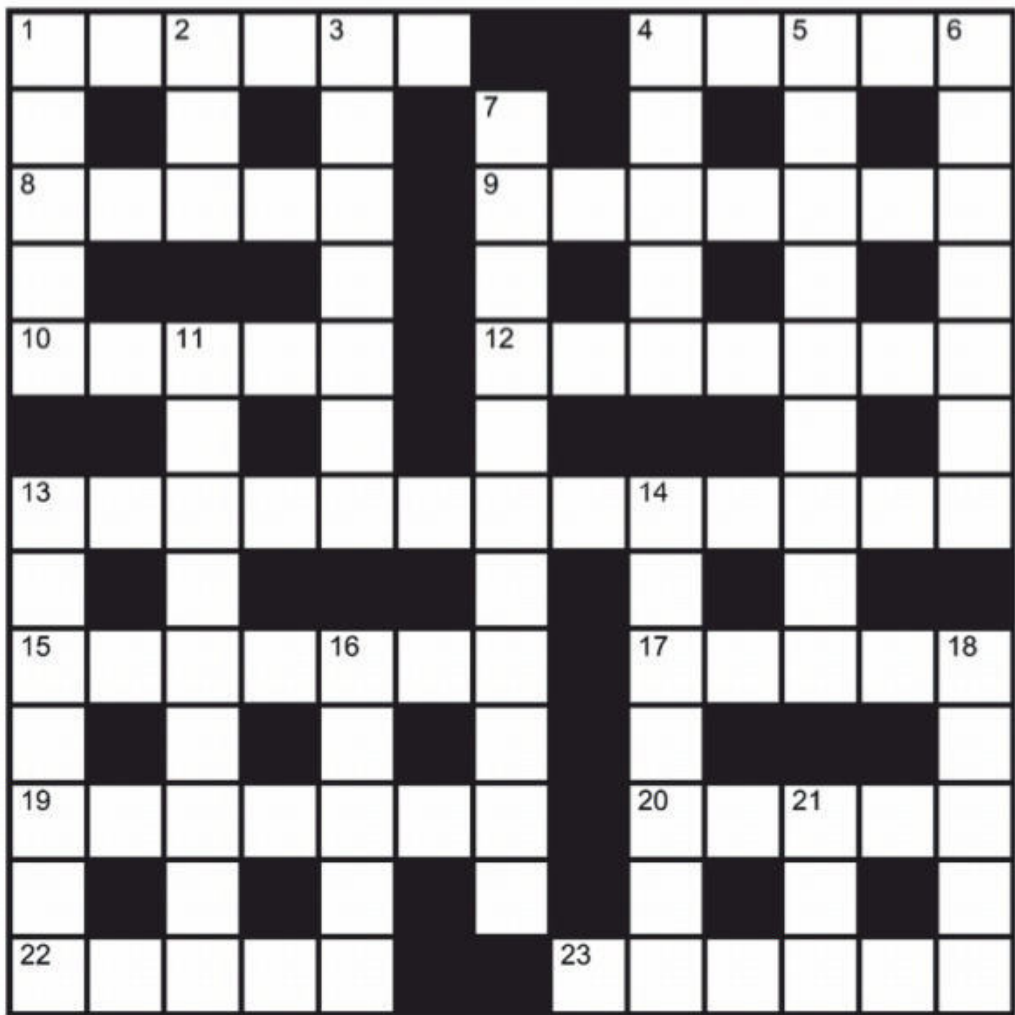
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GIVE YOUR BRAIN A WORKOUT



ACROSS

- 1 Big ending by thin friend of Snow White (6)
- 4 Reportedly treated a mouth (5)
- 8 Leaving a student something to eat (5)
- 9 Get back concerning insurance (7)
- 10 Journalist takes round whole plant (5)
- 12 Try a manoeuvre during swim in excursion (3,4)
- 13 Astronomical idea for a bright, bygone construction (3,4,6)
- 15 One Latin translation contains island origin (7)
- 17 Skilful with large earthenware (5)
- 19 A sly cop burst into song (7)
- 20 Trendy friend about to bloom (2,3)
- 22 Praise former spouse, bringing lot back (5)
- 23 Terribly green, unknown form of power (6)

DOWN

- 1 Dozens – that’s disgusting (5)
- 2 Genteel fellow has spirit (3)
- 3 Problem made literary character flip lid first (7)
- 4 A month, a year, showing gradual decrease (5)
- 5 As it happens, desperately poor left city (9)
- 6 Waste an award (7)
- 7 A gold prison somehow shows biblical character (8,3)
- 11 Follow girl to get a flower (3,6)
- 13 British choir performed on English bread (7)
- 14 Emperor owned Iran in a new layout (7)
- 16 Force rascal onto Spanish article (5)
- 18 Trifle with attorney before midnight (5)
- 21 Exclude from pub (3)

GETTY IMAGES

ANSWERS

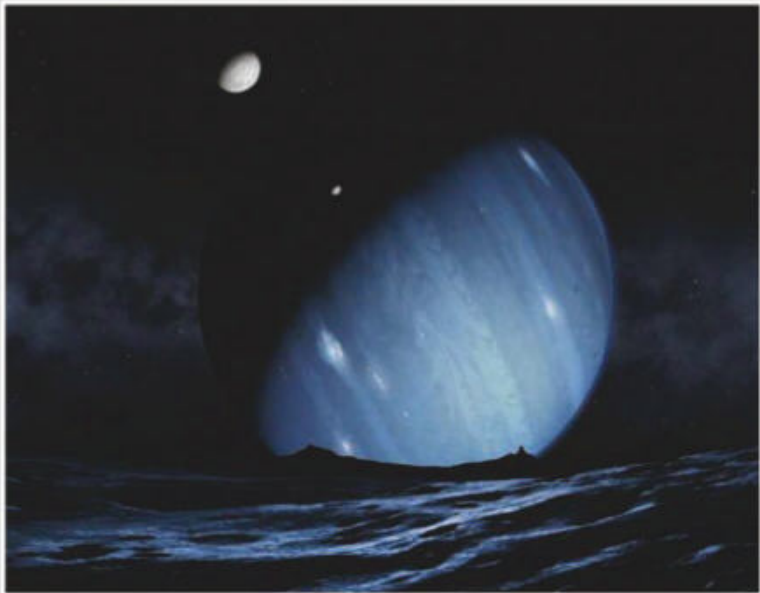
For the answers, visit bit.ly/BBCFocusCW
Please be aware the website address is case-sensitive.

NEXT ISSUE

COVER STORY

PLANET NINE

Is there a hidden world lurking in the outer reaches of the Solar System?



PLUS

THE OVERPOPULATION DEBATE

Some people are choosing not to have children in order to reduce their carbon footprint. But the argument isn't that simple.

ELECTROCONVULSIVE THERAPY

ECT has a reputation as a violent – even barbaric – treatment for mental illness. But with growing evidence of its effectiveness, we speak to those who are fighting to clear its name.

ON SALE 4 SEP



A SCIENTIST'S GUIDE TO LIFE

HOW TO SMELL NICE

IT'S WHIFFY, IT'S UNPLEASANT, AND MANY OF US HAVE SUFFERED FROM THE EMBARRASSMENT IT CAUSES, BUT WHAT IS THE BEST WAY TO DEAL WITH BODY ODOUR? DR CHRIS CALLEWAERT, AKA DR ARMPIT, TELLS ALL



WHAT CAUSES BODY ODOUR?

Lots of factors are involved – what you eat, your body mass index, the weather, your clothes and your genetic makeup, but the most important factor is the bacteria that live in your underarms. They feed on the lipids, amino acids and other molecules in our sweat. Some bacteria are better at breaking these materials down than others. Some leave unconverted molecules behind that start smelling bad. This causes body odour.

Everyone has their own unique cocktail of bacteria in their armpits. There are 'good', non-smelly bacteria, and 'bad', stinky bacteria. The balance is different for everyone.

WHICH UNDERARM PRODUCTS WORK THE BEST?

There are two main types of product. Deodorants contain perfume and antibacterial ingredients. These work well for most people. Antiperspirants have an extra ingredient – aluminium salts – which go into the sweat pores and help prevent sweating. These are good for people who sweat excessively.

ARE NATURAL DEODORANTS AND CREAMS ANY GOOD?

There's a trend for these products at the moment. Natural deodorants contain ingredients like essential oils that smell

nice and kill bacteria. These can work well, but some of the creams contain high concentrations of silver ions which could eradicate the microbiome. We need these bacteria. They help to protect us from pathogens. We've evolved with them. It's a futile idea to think that we can go on without them.

WHAT OTHER PRODUCTS ARE IN THE PIPELINE?

We've been doing bacterial transplants. You take the bacteria from people that smell good and 'transplant' or wipe them into the clean armpits of smelly people. The new bacteria colonise their armpits and the body odour is reduced. It can work well for a couple of weeks, so now we're developing a bacterial spray that people could use daily. It's currently in clinical trials.

WHICH FABRICS MAKE BODY ODOUR WORSE?

Synthetic fabrics like nylon and polyester capture moisture and odours, and selectively grow some bad, odour-causing bacteria. Natural fibres, like cotton, tend to be better and smell less.

WHAT FOODS CAN HELP ME SMELL BETTER?

People who eat more vegetables smell better and have more of the good bacteria. People who eat more fast foods and meat smell worse and have more of the bad bacteria.

WILL I SMELL MORE IF I GET STRESSED?

Some people do. When we're stressed, we release adrenalin which leads to more sweat production. This means that more lipids and amino acids are pushed out from the sweat glands and hair roots into the underarm. With all the bacteria that are already present there, this can lead to a burst of malodour. The only way out is not to get stressed about it. Psychology is a big part of this. Our research shows that women smell a bit better than men, and yet stress about body odour more. We need to use good products and try to worry less. **SF**

NEED TO KNOW...

1

If you don't sweat much, deodorant should keep you smelling sweet.

2

Avoid polyester and nylon. Stick to natural fibres like cotton.

3

Don't stress! The more you worry about body odour the worse it will get.

DR CHRIS CALLEWAERT
@DrArmpit
Chris is a microbial ecologist at the University of Ghent, Belgium. **Interviewed by Dr Helen Pilcher.**

ILLUSTRATION: MINET KIM

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